ACTA RADIOLOGICA

FOUNDED IN 1921 BY GÖSTA FORSSELL

PUBLISHED BY THE SOCIETIES OF MEDICAL RADIOLOGY IN DENMARK FINLAND NORWAY

DIAGNOSIS

MEDICAL IMAGING AND PHYSIOLOGIC RADIOLOGY

Vol 21 1980 Fasc 1

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Examples

BOIJSEN E and ZSIGMOND M Selective angiography of bronchial and intercostal arteries Acta radiol Diagnosis 3 (1965) 513

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MEDICAL IMAGING AND PHYSIOLOGIC RADIOLOGY

General Radiology

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Pediatric Radiology

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(overleaf)

A C T A   R A D I O L O G I C A

Vol 21
Fasc 1

DIAGNOSIS

1980

EDITORIAL

With this issue Acta Radiologica begins publication in a new form after having had the same appearance and been produced by the same processes ever since it was founded in 1921 by Gosta Forssell The design of the cover for the individual numbers has however been changed the table of contents being moved in 1951 to the front page in order to make it easier for readers to obtain information on the articles in the issue without having to open it And in 1963 the journal was divided into two series one on diagnosis and one on radiation therapy physics and biology

It is of great importance that the illustrations in a periodical presenting radiologic material should be of the highest quality If a reader is able by examining the illustrations to satisfy himself that the author has interpreted the images correctly he will also find it easier to evaluate the conclusions drawn in other words form a better opinion regarding the value of the article Even with blocks of high quality it has sometimes been necessary because of the size of the journal to present illustrations which in some cases have been too small with the result that some of the details could not be readily distinguished With increasing refinement of the imaging techniques and as ever smaller details have proved to have diagnostic significance a sense of dissatisfaction with the format of the journal has gradually developed A change over to a larger size has in fact been under consideration for several years but has been deferred until a change to a more modern method of production could be effectuated at the same time

As from the present issue the journal will be produced by means of modern computer generated phototypesetting and offset printing Other periodicals have earlier adopted the offset technique but in the opinion of the editors of this journal images produced with this process have only recently attained a quality that can be considered acceptable for use in radiologic publications Thus the change to offset was not made until comparative trials had brought conviction that the new method for image reproduction has reached a stage giving results comparable to those obtained with the old block making system

Apart from the change in appearance and the new method of production the principles of the journal will remain unchanged This means that the two series will continue to be published also in the future The diagnosis series will as before be a journal of general radiology with sidelines on some special fields such as neuroradiology and pediatric radiology In the future as in the past considerable attention will be paid to the layout in order to ensure that the articles are presented in a clear and esthetically attractive form

One of the reasons why Acta Radiologica was instituted was the desire to have a forum where experiences and results of research in radiology and allied fields in the Nordic countries could be published so that readily available information could be obtained regarding developments trends and future prospects in these countries As the speech communities covered by these countries are small the articles had to be published in one of the major languages of the world if they were to be available to readers in other areas In the beginning papers in English German and French were accepted However English has gradually become the dominant international language in the medical world holding a position almost comparable to that of Latin in the world of science during the Middle Ages and the centuries immediately following that period and the journal therefore subsequently adopted the policy of publishing articles only in English Summaries in German and French were retained but from this issue onwards they will be abandoned since it may be considered hardly possible these days to follow developments in any branch of medicine without a

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knowledge of English Acta Radiologica will therefore from now on be published exclusively in English

Although the journal was originally intended to be a forum mainly for the Nordic nations its pages have always been open to authors from other countries as well Many important articles by non Nordic writers have also been gratefully accepted for publication It is hoped that these contributions will not only continue but also increase in number Problems will thereby receive more all round treatment and comparisons with other points of view facilitated which should be to the mutual advantage of both Acta Radiologica and its readers

In recent years new diagnostic methods based on imaging techniques have been introduced ultrasound scintigraphy computer tomography and possibly still others such as magnetic resonance will appear in the future Opinions differ it is true regarding the appropriate speciality to which these methods should belong Acta Radiologica holds most emphatically that all imaging techniques should be concentrated to the radiologic departments where the basic skills are centered Furthermore the methods are as a rule such that the solution of a diagnostic problem is seldom gained by one method alone the methods are suppl to each other as well as to conventional Thus the most suitable way to achieve this is assemble them all at one institution In accordan with this opinion Acta Radiologica has publish and will continue to publish articles on all imag procedures In order to emphasize more clearly th previously the fact that the diagnosis section the series is a journal of medical imaging informati to this effect has been added to the first page of t cover It further appears that the journal will al accept reports on physiologic sequences analysab by radiologic methods in the widest sense

Like other clinical specialities oncology ne the methods offered by diagnostic radiology b otherwise they have little in common They shoul accordingly be practised by different specialists A a consequence of this Acta Radiologica as the onl radiologic periodical has run and will continue t run two series one diagnosis and one oncology th latter comprising not only radiation therapy but als chemotherapy and radiation physics and biology

With this declaration of its programme Act Radiologica is presented to the readers in its ne form

ROM THE DEPARTMENTS OF RADIOLOGY CARDIOLOGY AND SURGERY AND DIAGNOSTIC RADIOLOGY RE SEARCH LABORATORIES UNIVERSITY OF CALIFORNIA DAVIS CALIFORNIA 95616 USA

ANGIOGRAPHIC DETERMINATION OF SPLANCHNIC BLOOD FLOW

B M T LANTZ D P LINK J M FOERSTER and J W HOLCROFT

Treatment of bowel ischemia requires surgery Unfortunately the results are poor Embolization of the superior mesenteric artery leads to a mortality rate of 30 per cent Ischemia due to atheromatous obstruction may result in a 60 per cent mortality (JACKSON 1963 PURDUE & SMITH 1970) A major impediment to successful therapy is the lack of dia gnostic techniques which can identify reduced blood flow causing bowel ischemia Recently it has been reported that 70 per cent of bowel infarction is due to non-occlusive disease with venous occlusion ac counting for a further 10 per cent (BERGAN 1964 WILLIAMS et coll 1967) A high incidence of splanchnic atheromatous disease further compli cates the picture because it may not necessarily cause ischemia DERRICK & LOGAN (1958) reported a narrowed coeliac axis in 44 per cent of their autop sy series Unfortunately the surgeon at laparotomy may be no more successful than the radiologist at determining the presence of reduced vascular perfu sion (MARSTON et coll 1966 WILLIAMS et coll) The considerations mentioned suggest that a dia gnostic measure of splanchnic blood flow is needed With the application of videodensitometry during standard visceral angiography it appears that such a measure is now available

The splanchnic circulation can be defined as the blood supply to the liver spleen gall bladder pan creas and the gastrointestinal tract (stomach small and large bowel) The arterial supply to the splanch nic region originates from the coeliac superior and inferior mesenteric arteries The entire blood flow returns to the general circulation through the inferior vena cava via the liver and the hepatic veins In this respect the total splanchnic blood flow can be regarded as a single hypothetical organ However two different sources of blood for the liver exist the venous return from the gastrointestinal tract pan creas and spleen which is collected in the portal vein provides the liver with 70 to 75 per cent of its total blood flow (ROWELL 1975) and the remaining 25 to 30 per cent is supplied by the hepatic artery a branch of the coeliac artery

The splanchnic blood flow receives about 20 to 25 per cent of the resting cardiac output (BRADLEY et coll 1953 GRAYSON & MENDEL 1965) The blood volume contained in this region serves as a reservoir for maintenance of the cardiac output during stress for regulation of the systemic blood pressure Large blood volumes can be mobilized by constriction of the veins which have a large network of sympathetic innervation (MELLANDER & JOHANSSON 1968 ROSS 1971) Vasodilatation may be induced during eleva tion of the systemic blood pressure and during diges tion Thus splanchnic vascular resistance seems to be an important regulator and effector of the circula tory dynamics triggered by a variety of physiologic receptors (KORNER et coll 1967 BROOKSBY & DONALD 1971)

The total splanchnic blood flow can be estimated using the Fick principle i e the constant infusion technique originally described by BRADLEY et coll (1945) Clearance rates and hepatic extraction of indicator injected as a single bolus can also be used for estimation of the hepatic or the splanchnic blood flow (ROWELL 1974) Utilizing drug infusions or em bolization of selective branches of the mesenteric arteries it is possible to decrease or block part of the splanchnic circulation in patients with gastrointesti nal bleeding However to date there are no clinical

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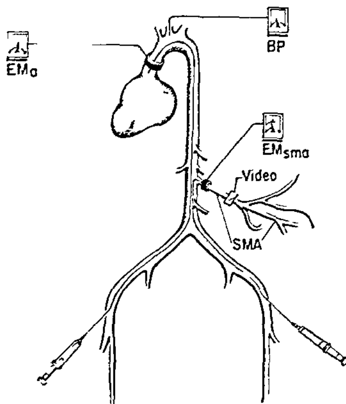


Fig. 1 Diagram of the canine model Flow in the ascending aorta (EM) and in the superior mesenteric artery (EM_{sma}) was measured using electromagnetic probes Angiographic catheter were positioned in the ascending aorta and in the superior mesenteric artery (SMA) The videodensitometric recordings and measurements were performed over a branch of the superior mesenteric artery (Video) Blood pressure (BP) was recorded via a carotid cannula and pressure transducer

ly useful methods for measuring regional blood flow in the splanchnic region

The objective of the present investigation is to validate a new method of determining blood flow in single splanchnic arteries as a per cent of cardiac output utilizing densitometry The technique has been compared to electromagnetic flow readings in a canine model and is intended to be used as a simple clinical method during routine abdominal angiography

Principles of videodensitometry The videodensitometric method of estimating relative blood flow has previously been described by LANTZ (1974 1975) and has proven to be highly accurate in a hydrodynamic model Application of the method has recently been tested in animal experiments regarding the renal circulation (LINK et coll 1979) and in humans with arteriovenous fistula (LANTZ et coll 1979) The densitometer records density changes in the television image caused by injected intravascular contrast medium In this respect it is a circulatory indicator dilution technique (WOOD et coll 1964)

The videodensitometric system is characterized high sensitivity and a rapid dynamic response l like conventional dilution techniques no samp catheters are needed After injecting iodine contra medium into the circulatory system and record the angiography on videotape cassette in const fluoroscopy with fixed kV and mA dilution cur can be obtained by placing a videodensitome cursor of appropriate size over any artery displa on the monitor

The concept of relative flow has previously be described in depth by LANTZ (1974) It is based up the principle of comparing flow at two sites of t circulation where contrast medium has been i jected The integrated areas of the two dilutio curves are inversely proportional to the flow at th sites of injection If for example the flow in th superior mesenteric artery is to be estimated as fraction of the cardiac output two contrast injec tions should be made one in the ascending aor where total cardiac output passes and one in th proximal part of the superior mesenteric artery B recording both dilution curves downstream at an site of the mesenteric artery the relative flow can b estimated according to (LANTZ 1975)

$$\frac{Q_1}{Q_2}=\frac{M_1\ A_2}{M_2\ A_1}$$

where Q_1 and Q_2 are the flows at the sites of injec tion M_1 and M_2 are the amounts of contrast mediu injected at the two sites and A_1 and A_2 are the integrated densitometric areas measured from the densitometric dilution curves at the same sit downstream in the peripheral vessel

Material and Methods

The blood flow in the superior mesenteric artery the hepatic artery and the splenic artery was es mated as a fraction of the cardiac output in an e vivo canine model (Fig 1) Estimates obtained b the videodensitometric method were compared to the corresponding electromagnetic flow readings in 4 mongrel dogs weighing between 22 and 27 kg The dogs were anesthetized with 30 mg/kg of sod pentobarbital and were ventilated with a Harvard pump on room air

Electromagnetic flow The cardiac output was continuously recorded by a circumferential ele

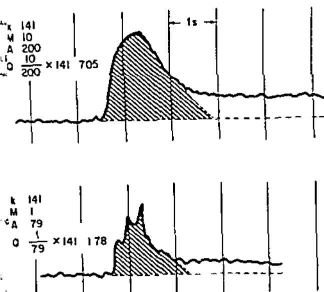


Fig 2 Videodensitometric flow calculation in superior mesenteric artery as a fraction of the cardiac output Top curve represents the recording obtained over the artery after injection of contrast medium into the ascending aorta Bottom curve represents the recording at the same site after selective injection into the artery The flow Q is calculated from M (amount of contrast medium injected) A (integrated densitometric area shaded) and k (calibration factor for radiation intensity) according to Q=M/A k The flow in the superior mesenteric artery as a fraction of the cardiac output is 1 78/7 05=25 2 per cent

tromagnetic flow probe around the ascending aorta 2 to 4 cm above the aortic valve Similar flow probes were attached to the proximal part of the superior mesenteric artery the splenic artery and the hepatic artery All probes were connected to electromagnetic flow meters (Statham SP 2200) The systemic blood pressure was simultaneously recorded from the left main carotid artery by an intra arterial cannula attached to a Statham P23DB pressure transducer

Videodensitometric flow The blood flow in a splanchnic artery as a fraction of the cardiac output was calculated from the videodensitometric dilution curves derived from a bolus injection of sodium iothalamate (Conray 400) through a 7 French pigtail catheter with its tip in the ascending aorta and from a second bolus injection through a 6 French selective catheter with its tip in a splanchnic artery With respiration suspended and the dog in a fixed position 10 ml of contrast medium was injected into the ascending aorta followed by an injection of 1 ml contrast medium into the splanchnic artery The selective injections were performed manually and the aortic injection by pressure injector (Cordis II) Eighteen series of injections were performed each containing one aortic injection followed by one or more selective injections at different time intervals During injections in the aortic arch and selectively into the splanchnic artery the video image was recorded on video cassette with the image intensifier in a fixed position over the splanchnic vessel examined Before each recording performed in constant fluoroscopy with fixed kV (65–80) and mA (3–5) a 10 mm aluminium filter was used for calibration of the radiation intensity The left posterior oblique position of the dog was used to separate a major part of the main branch of the splanchnic arteries from interfering smaller branches The videodensitometric dilution curves were displayed at a later time by replaying the cassette A videodensitometer with an output voltage proportional to the logarithm of the incident radiation was used (T Strand Siemens Elema Sweden) Integration of the videodensitometric mass time curves was performed by planimetry

Recording equipment The video image was recorded on a Sony Umatic video cassette recorder The data from the electromagnetic probes along with the arterial pressure was recorded on an Electronics for Medicine DR 8 photographic recorder and synchronized with the videotape recording of the contrast medium passage during fluoroscopy

Roentgen equipment A constant potential generator (C G R 1215 1200 mA) was used The fluoroscopic equipment included a cesium iodide image intensifier with a plumbicon television camera (Coronarix C arm C G R triple field image intensifier) The four inch (10 cm) intensifier input was used in all experiments

Results

Eighteen series of measurements totaling 34 paired ratios of splanchnic flow to cardiac output were obtained by the videodensitometric and electromagnetic methods The densitometric recordings from a typical data pair is illustrated in Fig 2 Extrapolation of the densitometric curves from the aortic injection (Fig 2 a) and the selective injection into the superior mesenteric artery (Fig 2 b) was required because of remaining contrast medium in the tissues which prevents the curve from returning to baseline This is an accepted technique in other dilution methods

Superior mesenteric artery flow Twenty two paired data comparing the flow in the superior

Table 1

Twenty two measurements of the superior mesenteric artery flow as a fraction of the cardiac output were recorded by electromagnetic and videodensitometric methods Each of the 12 series represents one injection of contrast medium into the ascending aorta followed by one or more subsequent selective injections into the superior mesenteric artery at different intervals The difference in percentage between the two methods is displayed in column E

Series	n	Time (min)	Electromagnetic flow (ml/min)		Electro-magnetic ratio (per cent sup mes artery flow) (C)	Videodensitometric ratio (per cent sup mes artery flow) (D)	Difference D–C (L)
			Cardiac output (A)	Sup mes artery flow (B)			
1		0	2 400				
	1	1		250	10 4	11 8	1 4
2		0	2 370				
	2	2		306	12 9	14 3	1 4
	3	3		298	12 6	12 2	−0 4
	4	5		242	10 2	13 4	3 2
3		0	2 290				
	5	2		250	10 9	11 9	1 0
	6	4		282	12 3	11 0	−1 3
4		0	1 89[illegible]				
	7	1		508	26 8	26 1	−0 7
	8	3		500	26 4	26 8	0 4
5		0	1 744				
	9	1		524	30 0	28 6	−1 4
6		0	1 786				
	10	1		524	29 3	25 8	−3 5
	11	2		508	28 4	26 5	−1 9
7		0	1 720				
	12	2		442	25 6	24 4	−1 2
	13	3		426	24 8	25 1	0 3
8		0	1 770				
	14	2		519	29 3	28 4	−0 9
	15	4		473	26 7	29 2	−2 5
9		0	1 927				
	16	3		473	24 5	24 7	0 2
10		0	460				
	17	1		197	42 8	39 0	−3 8
	18	2		176	38 1	40 2	[illegible] 1
11		0	751				
	19	1		228	30 4	28 0	−2 4
	20	2		210	28 0	29 2	1 2
12		0	[illegible]				
	21	1		251	2[illegible] 0	29 1	0 1
	22	3		24[illegible]	28 8	32 7	3 9
							$\bar{x}$ = −0 22
							SD = 2 00

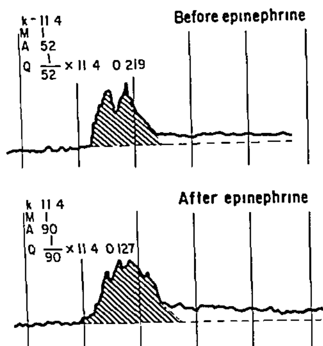


Fig 3 Effect of epinephrine One ml Conray 400 was injected into the superior mesenteric artery (top curve) giving a calculated videodensitometric flow of 0 219 The absolute flow recorded by the electromagnetic method was 279 ml/min Through the catheter 4 ml epinephrine (10 μg/ml) was injected Fourteen min later another 1 ml Conray 400 was injected into the artery The calculated flow using videodensitometry (bottom curve) was then 0 127 The corresponding electromagnetic flow was 163 ml/min The decrease of flow caused by epinephrine was 41 6 per cent by the electromagnetic method and 42 0 per cent by the videodensitometric method

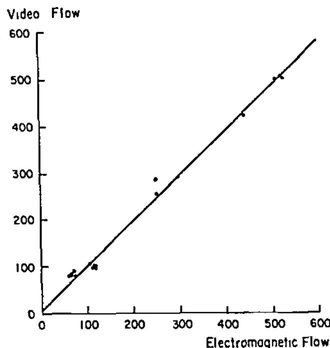


Fig 4 Correlation between blood flow simultaneously determined by the videodensitometric and electromagnetic methods in 34 measurements in splanchnic arteries (r=0 985) The solid line is a least squares regression line

mesenteric artery and the cardiac output were obtained (Table 1) The mean difference between the electromagnetic ratio and the videodensitometric ratio was −0 22 per cent (SD=2 00) This confirms the high accuracy of the videodensitometric method compared to the electromagnetic technique in the individual case The superior mesenteric artery/cardiac output ratio varied within the range of 10 to 40 per cent Higher ratios were found in experiments where the cardiac output was extremely low indicating inverse proportionality the larger the cardiac output the smaller the superior mesenteric artery flow However in the individual experiments the videodensitometric ratio did not differ from the electromagnetic one by more than 2 per cent This is illustrated in the change of flow induced by epinephrine infusion in the superior mesenteric artery causing a decrease in the flow of 41 6 per cent by the electromagnetic method compared to 42 0 per cent by the videodensitometric method (Fig 3)

Hepatic artery flow The hepatic artery flow in 7 experiments was calculated as 10 2 per cent by the electromagnetic method and 8 66 per cent by the videodensitometric method (Table 2) The mean difference was −1 54 per cent (SD=1 08)

Splenic artery flow Five paired data of the splenic artery flow ratio were calculated comparing the two methods The mean splenic ratio was 7 02 per cent with the electromagnetic method and 8 6 per cent with the videodensitometric method Thus the mean difference between the two techniques was 1 58 per cent (SD=0 58 Table 3)

Comparison between the electromagnetic and videodensitometric methods The splanchnic blood flow in absolute units (ml/min) was calculated in each of the 34 experiments from the videodensitometric ratio and the electromagnetic readings of the cardiac output according to

$$\frac{Q_S}{Q_A} \times (\text{cardiac output}) = \text{splanchnic blood flow in ml/min}$$

where

$\frac{Q_S}{Q_A}$ is the videodensitometric splanchnic flow ratio

The splanchnic flow in absolute units recorded by the two methods (Fig 4) correlated well (r=0 985)

Table 2

The hepatic artery flow as a fraction of the cardiac output obtained from 7 measurements in 3 series was estimated by the electromagnetic and the videodensitometric methods. Difference in percentage of cardiac output between the methods is displayed in column E

Series	n	Time (min)	Electromagnetic flow (ml/min)		Electro-magnetic ratio (per cent hepatic artery flow) (C)	Videodensito-metric ratio (per cent hepatic artery flow) (D)	Difference D-C (E)
			Cardiac output (A)	Hepatic artery flow (B)			
13		0	1 000				
	23	2		119	11.9	9.5	−2.4
	24	4		109	10.9	7.6	−3.3
14		0	1 057				
	25	2		119	11.3	9.5	−1.8
	26	3		134	12.7	11.3	−1.4
15		0	1 346				
	27	1		114	8.5	7.6	−0.9
	28	6		111	8.2	7.2	−1.0
	29	7		106	7.9	7.9	0.0
					$\bar{x}$=10.2 SD=1.96	$\bar{x}$=8.66 SD=1.49	$\bar{x}$=−1.54 SD=1.08

Table 3

The splenic artery flow was measured as a fraction of the cardiac output by electromagnetic and videodensitometric methods. Three series containing 5 paired determinations in percentage of cardiac output are displayed with the difference between the two methods in column E

Series	n	Time (min)	Electromagnetic flow (ml/min)		Electro-magnetic ratio (per cent splenic artery flow) (C)	Videodensito-metric ratio (per cent splenic artery flow) (D)	Difference D-C (E)
			Cardiac output (A)	Splenic artery flow (B)			
16		0	980				
	30	1		65	6.6	8.6	2.0
	31	3		70	7.1	9.1	2.0
17		0	1 057				
	32	1		64	6.1	7.6	1.5
	33	6		60	5.7	7.5	1.8
18		0	769				
	34	3		74	9.6	10.2	0.6
					$\bar{x}$=7.02 SD=1.54	$\bar{x}$=8.6 SD=1.12	$\bar{x}$=1.58 SD=0.[illegible]8

Discussion

Several factors should be seriously considered when using the videodensitometric technique for accurate flow measurement in selective arteries In the clinical setting one catheter alone might be used for contrast medium injections in the aortic arch and in a selected splanchnic vessel The catheter should contain at least 3 or 4 side holes close to the tip of the catheter to obtain a high injection rate in the ascending aorta It is then advisable to wait at least five minutes to avoid flow changes in the splanchnic region caused by the contrast medium Then the catheter will be withdrawn from the aorta and placed with its tip in the proximal part of the artery to be examined It is important that the side holes do not spill contrast medium directly into the abdominal aorta during the injection of contrast medium If this happens the densitometric area recorded from the selective injection will be spuriously low due to the spillover of contrast medium

During the injection into the ascending aorta the contrast medium will be well mixed with the blood flow at the site of injection However the selective injection in the splanchnic vessel should be performed manually over at least two seconds Previously (LINK et coll) it was found that an important error in the videodensitometric method is introduced when the injection rate approaches the blood flow at the site of injection Thus when the injection flow rate was greater than one half the arterial flow rate there was an obvious discrepancy between the videodensitometric and electromagnetic methods It has also been shown that perfect mixing of the contrast medium with the flow does not seem to be of great importance during selective injection into the artery since the videodensitometric window measures the total amount of contrast medium over an arterial cross section rather than local concentrations of medium within the vessel The effects of contrast medium after selective injection into the splanchnic vessels can be neglected as they occur after the densitometric curve has been obtained over a main branch of the arterial tree If a repeated injection into the splanchnic vessel is conducted it is again advisable to wait several minutes to obtain baseline flow

The objective of this investigation was to compare the accuracy of the videodensitometric method with a known standard the electromagnetic method The individual experiments showed an extremely good correlation (r=0 985) The technique can easily be used to compare the effects of different drugs in the superior mesenteric artery (Fig 3) The relationship among the flows in the splanchnic arteries can be compared by making a reference injection in the aorta above the origin of the coeliac axis not necessarily in the ascending aorta The video camera would be positioned in a field covering the superior mesenteric hepatic and splenic arteries Then the same reference injection would be compared with each selective injection into these arteries In the present investigation the hepatic artery flow was estimated to about 10 per cent of the cardiac output and the corresponding figure for the splenic artery flow was 7 per cent On the other hand the flow in the superior mesenteric artery varied over a wide range (10–40% of the cardiac output) This could be due to a block of the compensatory mechanisms in that region caused by the extensive surgery required to attach the electromagnetic probes Dissection of the superior mesenteric artery in its proximal part involves the ligation of multiple splanchnic nerves and this may destroy regulation of the blood flow

The videodensitometric method seems to have several advantages over the previously described spillover technique (OLIN & REDMAN 1966 GIANTURCO et coll 1970) With this technique the blood flow in the superior mesenteric artery is estimated at angiography by increasing the rate of injection into this artery until spillover of contrast medium appears on the films Multiple injections of higher and higher dose can be time consuming and may subject the patient to more risk from the injections of contrast medium than the benefits gained from the flow measurements Other methods using dye dilution techniques involve catheterization of the superior mesenteric vein as well as arterial catheterization Venous catheterization can be performed through transhepatic techniques or by catheterization of the umbilical vein Both procedures carry some adherent risk and are time consuming

The present investigation proposes the videodensitometric method as a simple clinical tool for estimating flows in splanchnic arteries as a fraction of the cardiac output The simplicity of the method makes it well adapted to flow measurements during routine abdominal angiography and will give important functional data of the splanchnic flow not readily available by other means With the aid of a densitometer and a videotape or cassette recorder the measurements can be performed by the radiologist during routine angiographic procedures

SUMMARY

A new videodensitometric method of measuring blood flow in the splanchnic arteries as a fraction of the cardiac output was compared to electromagnetic flow readings in dogs A previous investigation regarding the accuracy of the method in vitro was extended to prove that the videodensitometric technique was highly accurate also in vivo The simplicity of the technique suggests that the videodensitometric method could be used to estimate blood flow in splanchnic arteries during routine angiography

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ANGIOGRAPHY IN UTERINE AND ADNEXAL TUMORS

S KARLSSON and P H PERSSON

Angiographic evaluation of gynecologic and obstetric lesions was introduced in 1952 by BORELL et coll followed by several later publications (BORELL & FERNSTROM 1953 1954 BORELL et coll 1955) The appearance of the uterine artery and its branches in cases of pelvic masses was described by FERNSTROM (1955) At that time the common angiographic technique was aortography and the diagnostic accuracy was poor Later the angiographic technique improved and the value of bilateral selective internal iliac angiography was pointed out by ALTEMUS (1968 1969) Selective angiography of the ovarian artery was introduced by KAHN & FRATES (1968) and FRATES (1969)

However angiography is seldom performed in the preoperative evaluation of adnexal tumors although LANG (1967) stated The single most important advice toward an accurate preoperative diagnosis in the assessment of pelvic tumors can be attributed to the introduction of pelvic angiography to the diagnostic examinations of this area

Since then ultrasound has come into extensive use and later to some extent also computer tomography They are both easy and non invasive procedures but they fall short in differentiating between malignant and benign tumors

The angiographic appearance and the usefulness of angiography in patients with a pelvic mass were investigated in a prospective series and the results are now reported

Material and Methods

The material consisted of 106 females with a palpable pelvic tumor 63 of these being non symptomatic and without previous history of gynecologic tumors These 63 have been presented previously (KARLSSON & PERSSON 1979) In all patients ultrasound examination confirmed the palpated mass before pelvic angiography All of the patients were operated upon and microscopic diagnosis of the tumors obtained The age of the patients varied from 27 to 80 years mean 55

The angiographic technique was the same as described previously (KARLSSON & PERSSON) Lumbar aortography and selective bilateral internal iliac angiography were performed in all 106 patients selective catheterization of the ovarian artery was performed in 8 The diameter of the arteries of interest was measured with a scale lupe with 10 times magnification

Results

Anatomic considerations One great difficulty in angiography of the uterus and the adnexa is that they receive their blood supply from four sources i e both ovarian arteries and both uterine arteries (Figs 1 2)

At aortography the ovarian artery was demonstrated on one side or both in 66 of the 106 patients (62%) the origins of the ovarian arteries could be determined in 85 (Table 1) When bilaterally demonstrated (29 patients) the origins were not separated in height by more than 1 cm except in one case in which the origin of the left artery was at the level of the upper border of L2 and the right at the upper border of L3 i e a difference of about 3 cm

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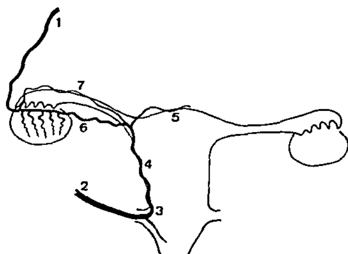


Fig 1 Drawing of normal uterus and adnexa 1 Ovarian artery 2 Uterine artery in its parametrial course 3 Junction of para metrial and marginal parts 4 Uterine artery in its marginal course 5 Fundal branch 6 7 Tubo-ovarian branches

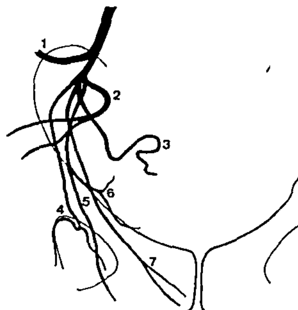


Fig 2 Branches from the normal iliac artery 1 Superior g artery 2 Inferior gluteal artery 3 Uterine artery 4 Obt artery 5 Internal pudendal artery 6 Vesical artery 7 I haemorrhoidal artery

The origin of the following main branches of the internal iliac artery could be determined the superior and the inferior gluteal artery and the inter nal pudendal artery the three groups suggested by NILSSON (1967) could be distinguished The origin of the uterine artery the vesico vaginal arteries and the middle haemorrhoidal artery could not be de termined but these arteries could be identified by their typical course in the pelvis The obturator ar tery had its origin from the external iliac artery in 33 cases (30%) in 16 cases bilaterally in 11 from the right and in 6 from the left side In 2 cases an acces sory pudendal artery was demonstrated

Fibromyomas were found in 34 patients aged 31 to 78 years mean 56 The vascularity of the tumors is given in Table 2 In 28 of these 34 cases irregular tortuous vessels combined with arched capsular vessels typical for myomas (FERNSTRÖM 1955) ap peared The remaining 6 cases had no intrinsic ves sels at all but in 5 of them loss of tortuosity o marginal segment of the uterine artery and la displacement of the parametrial–marginal jun indicated enlargement of the uterus (ALTE 1969) In one patient the uterine arteries were demonstrated depending on severe atheromat Intramural and subserous myomas occurred i patients pedunculated myomas in 4 and one pa had an intraligamental myoma (Fig 3) The ar graphic appearances of all these myomas were same except in one of the patients with a pedu lated myoma in whom a typical pedicle was d onstrated

The width of the uterine arteries could be m ured in all patients but one (Table 3) The sum of width of the two uterine arteries increased with size of the myomatous uterus The two arte sometimes differed markedly in diameter on the sides the wider artery supplying the m jor par

Table 1

Level of origin of the ovarian artery ob served at aortography

First lumbar vertebra	3
Second lumbar vertebra	60
Third lumbar vertebra	18
Right renal artery	[illegible]
Left renal artery	2
Total	85

Table 2

Degree of vascularity of the myomas related to si e

Size (cm) of uterus/myomas	Intrinsic vessels		
	Many	Few	No
–4 9	3	1	1
5 0–9 9	6	2	[illegible]
10 0	13	3	3





Fig 3 Bilateral internal iliac angiography in a patient aged 59 with an intraligamental myoma a) Early and b) late arterial phase Vessels of the normal uterus (→) left uterine artery stretched in its parametrial course (↔) The myoma is outlined by arrows in (b)

the myoma In 7 of the cases the ovarian arteries were demonstrated at aortography in 3 of them bilaterally The diameter of the ovarian artery varied from 1 0 mm to 3 0 mm In 5 of the patients a small ovarian cyst on one side was also revealed at operation One case with a 22 cm myomatous uterus had bilateral small endometrial cysts which were not demonstrated at angiography A stalked myoma was erroneously considered as an ovarian carcinoma One patient had besides the myoma pathologic vessels at the site of the left ovary Operation proved this to be an old inflammatory lesion

Benign ovarian tumors were found in 32 patients aged 27 to 80 years mean 56 (Table 4) 3 of them had bilateral tumors At aortography the ovarian artery was demonstrated in 19 patients in 17 of these on the same side as the tumor and in 11 cases bilaterally The artery on the tumor side was at least 0 5 mm wider than the contralateral one in all but one case In 17 cases with an ovarian artery supplying the tumor a tubo-ovarian branch from the uterine artery on the same side was observed in 15 at selective iliac angiography In 24 patients a tubo-ovarian branch from the uterine artery supplying the tumor was demonstrated often as a single non tortuous branch stretched and arched along the surface of the tumor (Fig 4) In 10 of these 24 cases the branch supplying the tumor had a diameter of less than 1 mm in the remaining cases 1 mm or more In 6 patients with unilateral tumor bilateral tubo-ovarian

Table 3

Size of the myomas related to the sum of the diameters of both uterine arteries

Size (cm) of uterus/myomas	Width (mm) of the uterine arteries							
	1		3	4	5	6	7	8
–4 9	1		1	1	1			
5 0–9 9		1	1	2	3	3		
10 0–		1	2	6	6	2	1	1

Table 4

Benign ovarian tumors

Diagnosis	No of cases	Size (cm)	Contrast accumulation in tumor
Cystadenoma			
Simple and serous papillary	14	4–12	3
Mucinous	7	5–20	2
Teratoma	4	4–13	0
Endometrioid cyst	4	5–12	2
Fibroma	3	7–15	0



a



b

Fig 4 Simple cyst 6 cm in diameter in the left ovary of a 42 year-old woman Internal iliac angiography a) Early and b) late arterial phase Uterine arteries (→) of normal width the left stretched The left ovarian branch (↠) is supplying the cy which is not outlined



a



b

Fig 5 Woman aged 40 with a 5 cm endometrioid cyst of the left ovary not demonstrated at iliac angiography a) Early and b) late arterial phase The normal uterus is slightly displaced to the righ a single and tortuous ovarian branch (→) on the left side

branches were demonstrated the one on the side of the tumor being wider in all but one case No appreciable relationship was found between the width of the branches and the size or nature of the tumor nor was further branching of the main stem of any significance The appearance of the branch was the same in solid and cystic tumors (Fig 5) In 6 patients 2 with simple cysts 2 with mucinous cysts and 2 with fibromas no branches supplying the tumors were demonstrated Four of these patients had a severe atheromatosis while 2 had normal pelvic arteries



Fig 6 Iliac angiography in a 5? year-old woman with a left sided benign cyst. In the late arterial phase the shape and size of the cyst (→) is observed because of accumulation of contrast medium in its wall



Fig 7 Inoperable bilateral ovarian carcinoma in a 58-year-old woman The left uterine artery (↔) is infiltrated the right occluded by the carcinoma Abnormal vessels originating from the ovarian branch (→)

Tumors larger than 6 to 7 cm in diameter as a rule caused elongation and stretching of the parametrial course of the uterine artery on the same side Ovarian tumors larger than 6 cm always displaced the uterus over to the contralateral side In 2 cases a change of caliber of the vessels and irregularities of the type usually associated with malignancy were observed One of these patients had a localized fatty necrosis close to the left ovary and the other had a small benign endometrioid cyst

Accumulation of contrast medium within the tumor occurred in 7 patients In the capillary phase a faint rim of contrast medium in part of the tumor capsule was demonstrated (Fig 6) The tumor was well circumscribed in 2 cases with the rim clearly circumscribing the whole ovarian tumor The draining veins were demonstrated in 8 cases in 6 bilaterally with the same contrasting effect on both sides No difference was noted between cases of solid and cystic tumors

Malignant ovarian tumors were found in 28 patients bilaterally in 8 The age of the patients varied from 29 to 77 years mean 58 Type size and vascularity of the tumors appear in Table 5

In all cases but 2 an ovarian artery was demonstrated on the side of the tumor at aortography Bilateral ovarian arteries were found in 12 cases 4 of which had bilateral tumors When bilaterally demonstrated the ovarian artery on the tumor side was always wider than the one on the contralateral side In 2 cases with bilateral carcinomas the larger carcinoma measured 6 and 9 cm in diameter respectively while the contralateral malignant ovary was of normal size In these 2 cases only the ovarian artery on the side of the larger tumor was demonstrated Pathologic vessels were filled from both the ovarian artery and from the tubo-ovarian branch no pathologic vessels were found in the two malignant ovaries of normal size Four of the bilateral carcinomas were large measuring 20 to 25 cm and 3 of these had no pathologic vessels from either the ovarian arteries or tubo ovarian branches The fourth of these large bilateral carcinomas obtained

Table 5

Malignant ovarian tumors

Diagnosis	Size (cm)	Pathologic vascularity			
		Rich	Medium	Sparse	None
Adenocarcinoma	4–30	4	6	10	5
Struma ovarii	7–1?		2		
Teratoma cystic	?0	1			

pathologic vessels from the tubo ovarian branch (Fig 7)

Of the 20 cases with unilateral carcinoma tubo ovarian branches were demonstrated bilaterally in 4 cases in 2 of these it was wider on the tumor side and in one case wider on the side of the normal ovary In one case the tubo ovarian branch had the same width on both sides In 3 cases further branching of the main stem of the tubo ovarian branch was demonstrated all in tumors smaller than 10 cm one of them cystic Two cases had pathologic vessels from a wide ovarian artery (Fig 8) the other 16 from the tubo ovarian branch

Pathologic vessels were sparse in 10 cases and absent in 5 (Table 5) Four cases had a rich vascularity which was not related to degree of malignancy size or nature (solid–cystic) of the tumor (Fig 9) In 3 cases with extensive tumor growth pathologic vessels from the inferior mesenteric artery or the middle haemorrhoidal artery were demonstrated In no case was infiltration of the bladder arteries observed

The diameter of the ovarian artery varied from less than 1 mm to 3 5 mm The diameter of the tubo-ovarian branch as measured at the uterine cornu also varied from less than 1 mm up to 3 5 mm No relationship could be found between the width of the ovarian artery or the tubo ovaria branch and the size of the tumor or degree of malignancy

In 7 patients the draining veins were well observed in 6 bilaterally and with the same contrasting effect Another 3 cases had a faint venous phase No obvious early filling of the veins was demonstrated

Tumors of uncertain malignancy Whether the tumor was malignant or benign could not be established with certainty in 6 patients The age of these patients varied from 50 to 73 years The tumors were 3 serous cystadenofibromas 1 cystadenoma and 2 mucinous cystomas At fine needle aspiration biopsy preoperatively in 2 of these cases malignant cells had been found Both cases had serous cystadenofibromas and the ovarian tumours were bilateral in both cases Angiography showed pathologic vessels from the tubo-ovarian branch on only one side in both these cases The other 4 cases had no pathologic vessels 3 of them had a tubo ovarian branch supplying the tumor but it was not infiltrated One patient had a severe atheromatosis not permitting any diagnosis

Inflammatory lesions and miscellaneous Two patients had old hematomas One measured 5 cm and was encapsulated after bilateral salpingo oophorectomy 3 years previously The other one was a descended rectus sheath hematoma and at palpation considered to be an ovarian tumor The angiography was normal in both



Fig 8 Large malignant cystic teratoma in a 55 year old woman Solid excrescences with abnormal vascularization in part of tumor

Two patients had unilateral sactosalpinx measuring 5 and 8 cm respectively In both cases the ovarian artery was wide on the same side 1 5 and 2 mm respectively Both these lesions were richly vascularized with a marked accumulation of contrast medium in the caudal part of the sacs The vessels had the same appearance as in a malignant lesion but the vascularity was more extensive than in ovarian carcinoma In these cases an early arterio venous shunting to the ovarian vein was demonstrated

Two patients had leiomyosarcoma originating from the small intestine both at palpation consid-



a



b

9 Large carcinoma in the left ovary of a 54-year-old woman Internal iliac angiography Tumor vessels filled b) Selective ovarian angiography More extensive filling of the vessels ovarian artery markedly widened

ered to be ovarian carcinoma Both tumors had a rich vascularity with pathologic vessels from the inferior mesenteric artery One case had a normal internal iliac angiography and gynecologic origin could thus be excluded (Fig 10) The other patient had pathologic vessels from the lateral sacral arteries as well as from branches of the gluteal arteries The origin of the tumor in this latter case could not be determined as uterus and the right adnex were involved in the large tumor mass

Discussion

The ovarian arteries generally take their origin from the antero-lateral part of the aorta but may originate from one or both renal arteries most commonly the right In autopsy materials this is reported to occur in 6 to 12 per cent by GERARD (1913) HASELHORST (1926) and JOACHIMOVITS (1931) but by ELISKA (1961) in 22 per cent In 2 to 10 per cent two or more ovarian arteries originate from the aorta on one or both sides (GERARD JOACHIMOVITS) In the present material only 4 of 85 ovarian arteries originated from a renal artery No case of double ovarian arteries was observed The difference between findings at autopsy and at angiography may be explained by the fact that the ovarian artery is small and usually insufficiently filled partly due to layering of the contrast medium partly to low flow in the narrow artery

In the present material an ovarian artery was demonstrated in 62 per cent of the cases as compared to BORELL & FERNSTRÖM (1954) who reported only 20 per cent Technical factors may account for this difference Possibly aortography performed in prone position of the patient might improve the information

Fibromyomas The results (Table 3) confirm those of FERNSTRÖM (1955) In cases of large myomas he found an arched and non-tortuous course of the uterine artery in the parametrial and marginal part ALTEMUS (1969) pointed out that the junction of the parametrial and marginal portions of the uterine artery becomes laterally displaced in cases of uterine enlargement and that this abnormality was pathognomonic These findings were confirmed in



Fig 10 Leiomyosarcoma of the small bowel in a 63 year old woman Aortography Large amount of pathologic vessels originating from the mesenteric arteries (→)

the present material In cases of very large myomatous uteri the part of the main trunk running along the lateral pelvic wall looked shortened and the artery then took a direct course in latero cranial direction without the general horizontal course in the parametries The uterine artery is often wide and divides directly into few and non tortuous arched vessels In none of the 5 cases with very large 20 cm or more myomatous uteri was the vascularity rich the intrinsic vessels were few in 2 cases and absent in 3

As FAULKNER (1944) noted and FERNSTRÖM confirmed the two uterine arteries often differed in width the wider artery supplying the major part of the myomas According to ALTEMUS (1969) extra uterine pedunculated myomas characteristically have a unilateral dilatation of the parametrial and marginal portion of the uterine artery unaccompanied by enlargement of the uterus Two of the 4 cases with pedunculated myomas in the present material had this appearance while the other 2 had uterine arteries of the same width The peduncu lated myoma falsely considered to be an ovar carcinoma had an angiographic appearance indica ing myoma at re examination of the films

A rich vascularity occurred in 22 myomas of (65%) but with increasing size, a tendency to le vascularity was found In such cases the diagno may be established by a lateral displacement of th parametrial–marginal junction only or, if de onstrated a lateral displacement of the marginal pa

Ovarian tumors Detailed demonstration ovarian and adnexal lesions requires demonstratio of the tubo ovarian branches of either the ovar artery or the uterine artery This is not adequatel obtained in aortography (DE DOMINICIS et col 1964 MARANTA et coll 1964 LANG 1967 SMIT 1971) FERNSTRÖM described tubo ovarian branch in 42 of 71 cases with adnexal tumor the demonstr tion not being related to size or type of tumor H could relate the presence of a non tortuous a arched branch to the size of the tumor and the wid of the branch to the nature of the tumor, sol tumors having wider branches than cystic one Further branching of the main stem of the tub ovarian branch was present more often in cases solid tumors In this material no correlation betwe the width or the appearance of the tubo ovari branch and the size or nature of the tumor wa found However branching of the tubo ovari main stem is more often present in cases of soli benign tumors and in cases of malignant ovar tumors

With pelvic angiography the size and shape of benign ovarian tumor is only rarely demonstrated FERNSTRÖM obtained good demonstration of the whole adnexal tumor in only one case a richly vas cularized ovarian fibroma In the present material benign ovarian tumors were entirely demonstrated both were simple cysts and had a rim of contrast medium in the wall in the capillary phase A satisfac tory estimation of the size of the tumor but not the shape was given when the tubo ovarian branch en circled the tumor to at least half the circumference which occurred in about one fourth of the benign cases

An ultrasound examination is mandatory to show the existence of an ovarian tumor and to determ its size shape and nature These last three qualities were impossible to evaluate angiographically in 30 of the 32 patients with benign ovarian tumors in the present material

In patients with malignant tumors the ovarian ar

Table 6

Reliability myomas

Size (cm)	No of patients	Correct diagnosis	False negative
– 5	5	4	1
6–15	10	9	1
6–	19	19	–
Total	34	32	2

Table 7

Reliability benign ovarian tumors

Size (cm)	No of patients	Correct diagnosis	False negative
– 5	9	8	1
6–15	18	17	1
16–	5	5	–
Total	32	30	2

Table 8

Reliability ovarian carcinomas

Size (cm)	No of patients	Correct diagnosis	False negative
– 5	3	2	1
6–15	17	16	1
16–	8	5	3
Total	28	23	5

tery on the tumor side was more frequently demonstrated than in patients with benign lesions However neither the diameter of the ovarian artery nor the diameter of the tubo ovarian branch is of any significance in the differentiation between malignant and benign ovarian tumors ALTEMUS (1969) noted a marked dilatation of the vessels comprising the ovarian arcade in 4 cases of ovarian malignant tumors all solid and extremely vascular He noted irregular distribution of contrast medium within a tumor in one case a malignant ovarian teratoma

The only criterion of malignancy is the presence of pathologic vessels whereas other angiographic parameters typical of malignancy such as accumulation of contrast medium early arterio venous shunting irregular distribution of contrast medium within a tumor etc are of much less importance

Atheromatotic abnormalities in the pelvic vessels occur first in the uterine artery probably due to postmenopausal uterine involution Such a lesion in the uterine artery must not be considered as malignant infiltration both conditions having the same angiographic appearance

In this material 3 of 4 cases with bilateral ovarian carcinoma and large tumor masses had no pathologic vessels and this was probably due to tumor necrosis In 2 cases of unilateral tumor one being a 9 cm cystadenocarcinoma and the other a 5 cm adenocarcinoma no pathologic vessels were demonstrated but both these patients had advanced atheromatosis Irregular distribution of contrast medium within the tumor was observed in one of the malignant tumors (Fig 9) any obvious early arterio venous shunting was not observed

Thus 5 patients had malignant tumors which were considered benign 2 having advanced atheromatosis and 3 a large and necrotic tumor In 6 patients with large benign cystic tumors no tumor vascularity was demonstrated 4 due to advanced atheromatosis These two factors atheromatosis and tumor necrosis appear to be the main reasons for erroneous diagnosis at angiography in gynecologic tumors Also the size of the tumor is of importance In 2 cases carcinoma was found in an ovary of normal size and shape and without pathologic vessels The smallest angiographically diagnosed carcinoma in the present material measured about 4 cm in diameter and had a sparse vascularity

Inflammatory lesions may simulate malignant tumors Two patients with sactosalpinx had rich vascularized tumors The vascular appearance could not be distinguished from that in cases of malignancy

The reliability of the angiographic diagnoses appears in Tables 6 to 8

Thus taken together of 68 patients with ovarian lesions 38 benign and 30 malignant 5 false negative and 4 false positive diagnoses regarding malignancy were encountered the angiographic accuracy becoming 87 per cent Of the 34 myomas a correct diagnosis could not be reached in 2 (6%)

In 21 of the 106 patients (20%) the vascular appearance did not allow a definitive diagnosis whether the tumor was ovarian or not However 5 of these had widening of the parametrial–marginal junction and a uterine enlargement suggesting myoma

These figures show that angiography is a valuable examination and a good supplement to ultrasound examination for differentiating malignant and benign lesions and to discriminate between uterine and ovarian tumors

SUMMARY

A series of 106 patients with uterine or adnexal lesions is presented Bilateral selective internal iliac angiography proved to be valuable in the preoperative diagnosis of gynecologic tumors regarding their origin and in the differential diagnosis between malignant and benign tumors

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ANGIOGRAPHY IN ANGIOMATOUS LESIONS OF THE GASTROINTESTINAL TRACT

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Angiomatous lesions of the gastrointestinal tract ave rarely been encountered in the past GENTRY et oll (1949) reviewed 1400000 case charts at the Aayo Clinic and found 106 cases of gastrointestinal ngiomatous lesions A review of the literature cov ering the last century by DWYER & STEINLAUF 1964) revealed 200 cases During the past 15 years n increasing number of vascular abnormalities have been diagnosed with angiography (BAER & RYAN 1976 MOORE et coll 1976 BOLEY et coll 1977 b) The stated incidence in the previous reports obvi ously reflects a lack of recognition rather than the true incidence since many of these vascular lesions are too small to be diagnosed by traditional methods and may easily escape detection at surgery and au topsy

The term angiomatous lesion is used to encom pass terms like angioma hemangioma hamartoma angiodysplasia phlebectasia and telangiectasia which are frequently used indiscriminately and in terchangeably in the literature

These lesions may cause mechanical obstruc tion of the bowel intussusception perforation of the bowel and consumptive coagulopathy (Kasabach Merritt syndrome) but hemorrhage sometime massive is the major complication which may occur in 25 to 50 per cent of the cases (GENTRY et coll CALEM & JIMENEZ 1963)

This report presents the experiences of gastro intestinal angiomatous lesions at these hospitals draws attention to some conditions in which such lesions affect the bowel and emphasizes the value and limitations of visceral angiography as a diagnos tic tool

Material and Methods

Angiography was performed in 20 patients with gastrointestinal angiomatous lesions 11 females and 9 males ranging in age from 3 months to 28 years Their data are summarized in the Table Two pa tients were referred for angiography to evaluate the extension of angiomatous lesions already diagnosed The remaining 18 were referred because of un explained gastrointestinal hemorrhage 16 because of chronic intermittent low grade blood loss and 2 because of brisk rectal bleeding In the group of chronic bleeders the duration of symptoms ranged from 5 months to 12 years (median 1 year) Repeated barium examinations and endoscopy had failed to reveal the bleeding source in these cases No unre warding explorative laparotomy had been performed in any patient before the angiography

Results

Angiomatous lesions were found at angiography in all patients but 3 in whom lesions were sub sequently found at surgery (cases 2 4) and autopsy (case 1) In most patients the lesion was one cm or less in diameter

Surgery following angiography (14 patients) Excision of the lesion was performed in 5 patients and segmental bowel resections in 8 The angioma tous lesions were visible on the serosal surface of the bowel in 4 patients on the mucosal surface in 4 when the bowel had been opened according to the

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Table

Data on 20 patients with gastrointestinal angiomatous lesions

Case No	Sex/age*	Duration of symptoms	Type of angiography	Site of lesion		Extra gastrointestinal manifestation	Surgery
				Angiography	Other methods**		
1	F/82	3 yrs	Cc Ms	–	Esophagus stomach jejunum ileum and right colon	Tongue lungs liver and bone marrow	–
2	M/61	6 mos	Cc Ms	–	Jejunum	–	Segmental rese of jejunum
3	F/3 mos	1 mo	Ao	Jejunum and ileum	Jejunum and ileum	Skin	Diagnostic laparotomy
4	F/56	3 yrs	Cc Ao	–	Jejunum and ileum	Skin	Segmental rese of jejunum and
5	F/62	6 mos	Cc Ms	Right colon	Jejunum and sigmoid colon	Tongue	Segmental resec of jejunum and sigmoid colon
6	M/47	1 yr	Cc Ms	Ileum	–	Skin liver pancreas and spleen	–
7	F/57	5 days	Cc Ms	Ileum	Ileum	–	Ileo-cecal re section
8	F/24	2 yrs	Cc Ms Ao	Ileum and right colon	Ileum	–	Segmental resec of ileum
9	M/47	2 days	Cc Ms Mi	Cecum	Cecum	–	Excision of les
10	M/55	6 mos	Cc Ms	Cecum	Cecum	–	Excision of lesi
11	M/61	6 yrs	Cc Ms	Cecum	Cecum	–	Excision of lesio
12	M/70	9 mos	Cc Ms Mi	Cecum	Cecum	–	Right hemicolect
13	M/73	2 yrs	Cc Ms	Cecum	Cecum	–	Excision of lesio
14	F/74	1 yr	Cc Ms	Cecum	Appendix	–	Right hemicolecto
15	M/77	2 yrs	Cc Ms Mi	Cecum	Cecum	–	Excision of lesi
16	F/81	5 mos	Cc Ms Mi	Cecum	Cecum	–	Ileo-cecal resectio
17	F/76	6 mos	Cc Ms Ao	Cecum and transverse colon	Cecum and transverse colon	Tongue	Right hemicolec and later colect
18	F/67	6 mos	Cc Ms Mi	Transverse colon	–	–	Ligation of branc from middle co artery
19	M/58	–	Cc Ms Mi	Rectum and sigmoid colon	Rectum and sigmoid colon	Skin and right leg	Resection of sigmoid colon
20	F/58	12 yrs	Ms Mi Ao	Rectum	Rectum	–	–

At the time of the first angiography

Barium examination endoscopy surgery or microscopy

No further hemorrhage Cc = Celiac angiography Ms = Superior mesenteric angiography Mi = Inferior mesenteric angiograph
Aortic angiography

Table (*cont*)

iosis	Follow-up
ple angiectasias er s disease)	Died from recurrent bleedings after 5 yrs
ectasias in submucosa and cosa bleeding	Recurrent bleedings
icroscopic specimen	Recurrent bleedings
omatosis Groups of angiectasias in nucosa and mucosa irofibromatosis)	3 yrs
ectasias in submucosa and mucosa ler's disease)	Recurrent bleedings
ectasias in submucosa and mucosa sler s disease)	Recurrent bleedings
ectasias in submucosa and mucosa	Died postoperatively
mic stricture organized thrombi fibrosis (thrombocytosis)	5 yrs *
ectasias in submucosa and mucosa	5 yrs
ectasias in submucosa and mucosa is and ectatic vessels in subserosa	3 yrs
ectasias in submucosa and mucosa ding	5 yrs
tic vessels in submucosa sible A V fistula	6 mos
iectasias *in submucosa and mucosa*	6 yrs
iomatous lesion in mucosal diver ilum at base of small appendix	4 yrs
iectasias in mucosa and luminal t of submucosa	Died postoperatively
iectasias in submucosa Possible V-fistula	2 yrs
iectasias (Osler's disease)	Recurrent bleeding died after ?nd operation
microscopic specimen	Recurrent bleedings
ernous angioma in submucosa h phleboliths	23 yrs
microscopic specimen	Recurrent bleedings

angiographically *determined* location In the remaining 5 the lesion could only be identified in serial sections of the resected specimen In one patient (case 18) angiography demonstrated an *angiomatous* lesion in the transverse colon At laparotomy no gross abnormalities were found and ligation of a dilated branch of the middle colic artery was performed The bleeding episodes continued and angiography was repeated 2 years later but the previously observed lesion in the transverse colon could not be found

Nine patients have not bled again postoperatively 8 of these having been followed up for more than 2 years In one of them (case 8) a nephroangiography was performed 4 years later because of hypertension Though the patient had no symptoms from the bowel superior mesenteric angiography was carried out to control the operative result A renal artery aneurysm and an angiomatous lesion of the right *colon were demonstrated (Fig 1c) A review of the* films from the first angiography did not reveal any abnormality in the right colon despite the high quality of the films

Blood loss continued in 3 patients following surgery (cases 2 17 18) In case 2 no bleeding source has been found despite a repeat laparotomy repeated gastrointestinal barium examinations angiography and endoscopic procedures One patient (case 17) had a right hemicolectomy because of an angiographically demonstrated angiomatous lesion in the cecum A year later bleeding recurred and an emergency angiography demonstrated extravasation of contrast medium in the transverse colon and early contrast filling of dilated veins from that region corresponding to several small vascular lesions confirmed in the resected specimen The early contrast filling of dilated veins had been overlooked at the previous angiography but was not prominent and no extravasation had occurred The patient died from postoperative complications Another two patients (cases 7 15) who were poor surgical risks also died *postoperatively*

No surgery following angiography (6 patients) In a 3 month-old girl with rectal bleeding and angiomatous lesions of the skin a diffuse vascular abnormality involving two thirds of the jejunum and entire ileum (macroscopically regarded as a capillary hemangioma) was found at laparotomy (case 3) A subsequent angiography confirmed the extension of the lesion and no other organs were found to be involved (Fig 2) The bleeding episodes gradually subsided during a 3 year follow-up period on medical treatment

A second patient (case 19) was at 38 years of age resected for a bleeding angiomatous lesion (microscopically regarded as a cavernous hemangioma) diffusely infiltrating the sigmoid colon Now 20



a



b



c

Fig 1 Case 8 Patient with thrombocytosis intestinal hemorrhages and attacks of abdominal pain a) Superior mesenteric angiography enlarged ileal artery and filling of dilated veins during arterial phase (→) b) Microphotography of ischemic stricture mesenteric vessel occluded by organized thrombi (→) increased vascularization in the vicinity (↔) Weigerts elastin ×8 c) Superior mesenteric angiography (magnification view) 4 years later Angiomatous lesion in the right colon not present at previous angiography slow filling of dilated veins beginning in the arterial phase

years later recurrence of the disorder in the rectum and distal part of the colon was found at a routine rectoscopy followed by a double contrast colon examination (Fig 3 a) No symptoms were present At angiography poor contrast filling of the vascular lesion occurred slow circulation in the affected part of the bowel and several phleboliths were visible along the bowel wall (Fig 3 b) This patient also had angiomatous lesions of the right leg with varices since childhood including soft tissue and bone hypertrophy changes consistent with the Klippel-Trenaunay syndrome

In a third patient (case 1) the angiography was without evident abnormality but at autopsy 5 years later numerous angiomatous lesions were found in the gastrointestinal tract



a



b

g 2 Case 3 Infant with diffuse angiomatous lesion of the small testine Aortography a) Arterial phase enlarged superior esenteric artery (→) same width as the lumbar aorta b) Capillary phase Contrast accumulation within vascular spaces in jejunum and ileum and early filling of superior mesenteric vein (→) and portal vein (↔)

In a fourth patient (case 5) resection had been arried out of the jejunum and sigmoid colon be ause of angiomatous lesions When the bleeding pisodes continued postoperatively angiography vas performed but no bleeding source was ob erved Two years later angiography was repeated lemonstrating early contrast filling of dilated veins ining the right colon but the bleeding was not severe enough to require surgical intervention

A fifth patient (case 6 previously reported by NYMAN 1977) had a small angiomatous lesion in the ileum The low grade gastrointestinal hemorrhage could also have emanated from angiographically ob served multiple angiomatous lesions in the liver and pancreas

A sixth patient (case 20) had a rectal lesion found at endoscopy and angiography but it was not con sidered to represent the bleeding source

Among all 20 patients a solitary angiomatous le sion in the gastrointestinal tract was found in 13 and only one of these had similar vascular abnormalities in other organs Multiple lesions or a diffuse in volvement were present in the remaining 7 patients and all but one had similar abnormalities in other organs

Discussion

Angiomatous lesions of the gastrointestinal tract are solitary or multiple They may vary in size from a few mm to pedunculated or polypoid masses pro jecting into the bowel lumen or diffusely infiltrate large segments of the bowel wall adjacent soft tis sue or organs (WOOD 1967) The bowel lesion may be only one manifestation of a widespread vascular disorder with multiple organs involved such as in hereditary hemorrhagic telangiectasia Rendu Osler Weber disease (SMITH et coll 1963 HALPERN et coll 1968) blue rubber bleb nevus syndrome (BAKER et coll 1971 HAGOOD & GATHRIGHT 1975) Maffucci s syndrome (LEWIS & KETCHAM 1973) Kaposi s sarcoma (HAYLOCK 1963 KANTER et coll 1968 PALMER 1972 MANN 1974) Klippel Tre naunay syndrome (GHAHREMANI et coll 1976) and diffuse neonatal hemangiomatosis (HOLDEN & ALEXANDER 1970) Cutaneous angiomatous lesions



a



b

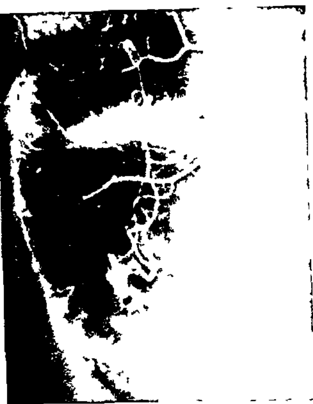


c

Fig 3 Case 19 Klippel Trenaunay syndrome a) Double c trast examination of rectum and distal colon with narrowing ampulla recti and flat indentations of the anterior aspect of bowel wall representing angiomatous lesions b) Inferior me teric angiography Filling of widened vascular space phleboliths along the bowel wall (↔) c) Microphotograph resected specimen 20 years previously groups of cavernous sels (→) in the submucosa with calcified thrombi Hemat eosin ×17

are not seldom found concomitant with visceral ones In the collective review of RISSIER (1959) this occurred in 30 per cent of the patients with intestinal lesions and in a pediatric age group the corresponding figures were 49 per cent (ABRAHAMSON & SHANDLING 1973)

Various classifications of angiomatous lesions in the gastrointestinal tract have been attempted based on macro- and microscopic appearances angiographic characteristics and clinical behaviour or combination of these (KAIJSER 1936 GENTRY et coll WOOD MOORE et coll) RISSIER pointed out that any classification is of limited value because the great overlap between various types F thermore the etiologic and pathologic factors probably multiple Various theories have been proposed angiomatous lesions may represent ited disorders congenital defects neoplastic


a


b

ıg 4 Case 10 Angıodysplasıa of rıght colon a) Vascular tuft ıth b) fillıng of a dılated submucosal vein durıng arterıal phase →)

proliferation vascular proliferation ın ınflammatory tates or be the result of a degenerative process of ıgıng mucosal ıschemia functional shunting or an angiogenesis factor (HANSEN 1948 SHEPHERD 1953 ROBINS 1968 WARNER & O LOUGHLIN 1975 BAER & RYAN BAUM et coll 1977 BOLEY et coll 1977b)

The most common type observed at angiography ıns the angiodysplasia ın the right colon (GENANT & RANNIGER 1972 SHEEDY et coll 1975 BAER & RYAN BAUM et coll BOLEY et coll 1977b ATHANASOULIS et coll 1978) They have the following features ın common (1) they occur predominantly ın patients over the age of 55 (2) are not associated with vascular lesions of the skin or internal organs (3) may produce chronic low grade or intermittent brisk rectal bleeding (4) are small usually 5 mm or less and can generally not be identified at surgery or at examination of the resected specimen unless special injection techniques are used and (5) cannot be detected by barium examinations and are only rarely identified with colonoscopy Angiography ıs therefore the primary method for their detection

In agreement with the literature the most common location of angiomatous lesions ın the present series was ın the right colon (12 patients) In 8 of these no vascular lesions were found outside the right colon and all 8 exhibited angiographic findings of angiodysplasia (Figs 4 5) ı e a slowly emptying dilated and tortuous intramural vein a capillary accumulation of contrast medium or vascular tuft or early contrast filling of a dilated vein (BOLEY et coll 1977a) Though ın one patient (case 14) the vascular abnormality proved to be confined to a short retrocecal appendix adherent to the colon at the pathologic examination thereby simulating a cecal angiodysplasia at angiography A similar case was reported by FOSTER et coll (1971)

In the remaining 4 patients the right colon lesions were associated with vascular lesions ın other parts of the bowel and ın other organs and they probably represent angiomatous entities different from right colon angiodysplasia Three of these 4 patients had hereditary hemorrhagic telangiectasia They belonged to the same age group as those ın whom angiodysplasia of the right colon occurs The angiographic features of the right colon lesions ın 2



a



b

Fig 5 Case 12 Angiodysplasia of the right colon a) Late arterial phase filling of a dilated submucosal vein b) Magnification view demonstrating the vascular tuft not seen in (a)

of the patients were the same as those described for angiodysplasia This emphasizes the importance of detailed coeliac superior and inferior mesenteric angiography even though a typical right colon angiodysplasia has been found In addition BAUM et coll reported that angiographic abnormalities considered to be angiodysplasia were presumably caused by cecal carcinoma in 2 patients and segmental right colitis in one Similar difficulties occurred in one patient with a cecal carcinoma not included in the present series

When bleeding is sufficiently severe and all examinations are normal except for an angiographic diagnosis of angiodysplasia of the right colon surgery is recommended If no other lesions are found to account for the hemorrhage at laparotomy a right hemicolectomy is the mode of therapy since angiodysplasia can be multiple within the right colon (BOLEY et coll 1977 b)

A diagnosis of hereditary hemorrhagic telangiectasia was made in 4 patients This disorder is probably due to congenital defects within the walls of small vessels resulting in angiomatous lesions with arteriovenous communications Any organ in the body may be affected and hemorrhage from gastrointestinal telangiectasia occurs in approximately 15 per cent of the patients with Osler s dis (SMITH et coll) No family history could be obta in 3 of the present patients with this disease H ever this does not exclude the diagnosis which based on the macro and microscopic appearan of the angiomatous lesions and the multiple or involvement At visceral angiography these lesi appear as single multiple or diffusely scattered v cular tufts of various sizes and with arterio nous shunting (HALPERN et coll LANDE et c 1976 NYMAN) Early contrast filling of dilated ve may be the only angiographic finding indicat telangiectatic lesions as in one of the present cas Previous bowel resections because of telangiecta lesions a previous normal angiography and a n mal double contrast colon examination in this p tient support the concept that the early filling ve draining the right colon were due to diffusely sca tered telangiectases which per se were too small be demonstrated at angiography Arteriovenous fistulas and arterial aneurysms are other features the disease

The presence of two angiomatous lesions and renal artery aneurysm in one case would suggest diagnosis of Osler s disease On the other hand th patient used oral contraceptives thrombocyt

is present and the examination of the resected al specimen demonstrated an ischemic stricture th fibrosis and organized thrombi Thus throm sis with infarction of the bowel wall and inflam atory reactions could have caused abnormalities at angiographically had an angiomatous character ig 1)

Angiomatous lesions of the bowel in patients with lippel Trenaunay syndrome have rarely been ocumented (GHAHREMANI et coll) The predomi ant form of the vascular abnormality in these cases ems to be a so-called diffuse cavernous hemangio a of the colon The vascular abnormality is con ned to the venous side with sluggish circulation rough the pathologic vessels where thrombi may velop and calcify appearing as phleboliths along e bowel wall (BEAN 1967) In one of the cases scribed by GHAHREMANI et coll a 9 year-old hild selective inferior mesenteric angiography owed slow circulation and marked retention of ontrast medium within the vascular spaces The tent of the lesions was well demonstrated Slow rculation was also noted in the present case as well phleboliths but only a few vascular spaces were itlined at angiography The bowel lesion had simi r angiographic features as those of the right leg t femoral angiography WESTERHOLM (1967) de ribed a patient with a diffuse cavernous heman ioma of almost the entire colon where angiography ras without evident abnormality while cavography esulted in retrograde contrast filling of the vascular bnormality

Patients with bleeding from angiomatous lesions f the gastrointestinal tract have often been sub ected to unrewarding abdominal explorations and lind bowel resections with a poor result since more raditional diagnostic methods have failed to dem onstrate the lesions and they could not be iden ified at surgery (KLEIN et coll 1971 BRUUSGAARD & JUHL 1974 SHEEDY et coll) When there is reason o anticipate that an angiomatous lesion may repre sent the bleeding source angiography should be car ried out if bleeding is of such severity that surgery is contemplated This is indicated in patients with known angiomatous lesions of external or internal organs or with a family history of such abnormali ties even though other lesions have been found to account for the hemorrhage and in patients with chronic or intermittent brisk blood loss when meticulous barium examinations and endoscopy have failed to reveal the bleeding source SHEEDY et coll in their series of 88 patients with chronic gas trointestinal bleeding of obscure origin found 22 patients with angiomatous lesions at angiography With angiography it is possible to determine not only the site of the lesion but also its extension and the presence of multiple lesions which influences the therapeutic approach It is usually not possible to demonstrate bleeding in terms of extravasation of contrast medium from angiomatous lesions since the hemorrhage generally is sparse

Though angiography is the primary method to detect angiomatous lesions of the gastrointestinal tract it is not possible to observe the vascular ab normality or its full extension in certain cases This may occur with diffuse cavernous hemangioma of the colon The difference noted between the cases with this disorder may be due to a more advanced thrombus formation in the lesions with increasing age In such cases endoscopy and barium examina tions may better demonstrate the extension of the vascular abnormality

In the present series no evident abnormality was found in 3 angiographic examinations In one case angiography was performed 5 years before the de tection of numerous telangiectatic lesions in the gas trointestinal tract at necropsy Since bleedings had been present for 8 years it was considered likely that the vascular lesions were present at the time of the angiography but were too small to be diagnosed In 2 patients angiomatous lesions with a diameter of approximately 1 cm were found at laparotomy fol lowing the angiography In one of these no abnor malities could be identified on the films even in retrospect in spite of the high quality of the ex amination In the other patient a lumbar aortography had been performed since catheterization of the su perior mesenteric artery failed

If coeliac superior and inferior mesenteric an giography reveal no abnormalities special tech niques at the examination of the superior mesen teric artery are recommended The use of 50 to 60 ml of contrast medium (60% meglumine salt) injected at a rate of 5 ml/s with films exposed over a time of 25 to 30 s magnification or coned down views especially of the right colon or any other area that was not well demonstrated on initial films may improve the information

In 3 patients of the present series vascular abnor malities enlarged or developed between two angio- graphic examinations over a period of one 2 and 4 years In addition recurrence of the vascular disor

der occurred after previous resection at the same site in one patient This sometimes progressive character of angiomatous disorders emphasizes the value of repeated angiographic examinations if no bleeding source is found at the first one or if bleed ing recurs after resection of such lesions

SUMMARY

Twenty patients with various angiomatous lesions of the gastrointestinal tract such as right colon angiodysplasia and manifestations of Rendu Osler Weber disease and Klippel Trenaunay syndrome are reported During the past 15 years an increasing number of such lesions have been reported diagnosed mainly by angiography The major complication from these vascular lesions is bleed ing Angiography is the primary method for their detection because of their often small size and is a prerequisite before surgery when reason exists for anticipating an angiomatous lesion as the source of bleeding However in certain cases angiography will fail to demonstrate the vas cular abnormality or its full extent

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ANATOMY OF THE PANCREATIC VEINS

A post mortem and clinical phlebographic investigation

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Selective catheterization of the pancreatic veins r clinical application can be performed using the rcutaneous transhepatic or the transumbilical ap- oach to the portal vein (GOTHLIN et coll 1974) Pancreatic phlebography is important in connec on with blood sampling for hormone assay in en ocrine tumours of the pancreas (INGEMANSSON 977 LUNDERQUIST et coll 1978) and is also of e in the morphologic examination of inflamma ry pancreatic disease and exocrine tumours REICHARDT et coll 1978) The description of the enous anatomy of the pancreas in textbooks is chematical and brief and often contradictory PE RÉN (1929) gave a more detailed description of the ancreatico-duodenal venous anatomy but mainly he pyloric and duodenal drainage With the increas ng frequency of pancreatic surgery in the early fif ies reports on the anatomy of the blood vessels of his region appeared (DOUGLASS et coll 1950 FAL ONER & GRIFFITHS 1950 DOEHNER et coll 1955) FALCONER & GRIFFITHS described the anatomy of the entire pancreas in 50 specimens mainly from a surgical point of view

The aim of the present report is to describe the venous anatomy of the pancreas and its variations to provide a guide for selective catheterization for blood sampling and to outline the normal selective phlebography of pancreatic veins

Post mortem phlebography

Material and Methods

The material comprised 22 human adult cadavers without signs or history of pancreatic disease

Injection technique At autopsy a polyethylene catheter with a diameter of 3 to 4 mm was inserted in a peripheral tributary of the superior mesenteric vein Preferably the ileocolic vein was used as this vessel is easily dissected without injury of other portal vein tributaries The tip of the catheter was advanced to the estimated position of the confluence of the superior mesenteric and splenic veins and the catheter was tied with a ligature Injury of other portal vein tributaries was carefully avoided

A modified Schlesinger buffered iodinated gelatin injection agent (HALES & CARRINGTON 1971) was prepared Barium sulphate was used as pigment and the solidification time was adjusted to about 30 min As rapidly as possible 150 to 200 ml of the agent was injected by hand since the consistency increased after only a few minutes Filling of smaller gastric veins and superficial veins of the liver and spleen indicated as a rule also filling of the pancreatic veins The agent was allowed to solidify for 45 min The abdominal and retroperitoneal organs were then re moved en bloc The portal vein was cut off at the hilum of the liver The main tributaries of the portal vein were identified and subsequently step by step the pancreas and its draining veins were dissected

In some early cases the abdominal and retro peritoneal organs were removed en bloc before the catheter was inserted into the portal vein in the hilum of the liver or into the splenic vein in the hilum of the spleen The periphery of the superior and inferior mesenteric veins was ligated In these in stances it was difficult to avoid leakage of contrast agent Injection of the contrast agent before removal of the organs was later found to be preferable

Radiographic technique In some instances sur vey films were exposed immediately after injection

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a



b

Fig 1 Radiography of pancreaticoduodenal specimens PV = portal vein SPV = splenic vein SMV = superior mesenteric vein IMV = inferior mesenteric vein ASPD = anterior superior pancreaticoduodenal vein PSPD = posterior superior pancreaticoduodenal vein PIPD = posterior inferior pancreaticoduodenal vein AIPD = anterior inferior pancreaticoduodenal vein CV = coronary vein a) In this specimen veins of the body of the pancreas drain to the coronary vein [...] of the tail of the pancreas drain to the splenic vein [...] this specimen a vein (→) drains a ventrocranial part of the head [...] the pancreas and the cranial part of the duodenum to the [...] vein Inflow of the vein not filled with contrast medium [...] dotted lines demonstrate its course as found by dissection [...] pullary shape of the periphery of duodenal veins (↔)



a



b

ıg 2 a) Dorsal aspect of dıssected specımen Small posterıor ıperıor pancreatıcoduodenal veın (⇸) domınatıng dorsal pan eatıc veın (⇸) An arcade runs ın the pancreatıcoduodenal sulcus caudally endıng ın the first jejunal veın (→) b) Ventral aspect at the hepatoduodenal lıgament CHV = choledochal veıns PV = portal veın GB = gallbladder P = head of pancreas

f the contrast agent However as the radıography quıpment of the autopsy room dıd not allow dequate examınatıon qualıty films were later on xposed only after ısolatıon of the pancreatıc tıssue vıth the specımen ın contact wıth fine graın films

In two ınstances only survey films wıth the pan reas ın sıtu were obtaıned As the specımens were lıssected before complete solıdıficatıon of the ınjec ıon agent fillıng of the pancreatıc veıns was ıncom plete ın some cases after dıssectıon However ın hese cases the veıns could be ıdentified by dıssec tıon and documentatıon of the anatomy was made by drawıngs or photographs

Results

Veıns of the head of the pancreas The anterıor aspect of the head of the pancreas was draıned maın ly by the anterıor superıor pancreatıcoduodenal veın ın 19 cases (Fıg 1) Thıs veın joıned the gastrocolıc trunk whıch ended ın the rıght lateral wall of the rıor mesenterıc veın wıthın 1 to 3 5 cm (average 2 cm) off the confluence of the splenıc and superıor mesenterıc veın (ın the followıng text named conflu ence)

In one case only tıny veıns ran to the gastrocolıc trunk and the maın ventral draınage was by the anterıor ınferıor pancreatıcoduodenal veın to the superıor mesenterıc veın An ant ınf veın was ıden tıfied ın 12 cases The veın ended ın the first jejunal veın ın 7 ınstances ın the superıor mesenterıc veın ın 4 and was a trıbutary to the anterıor superıor veın ın one case

The dorsal aspect of the head was usually draıned by the posterıor superıor pancreatıcoduodenal veın runnıng dırectly to the portal veın wıthın 1 5 to 3 cm (average 1 8 cm) off the confluence The post sup veın was ıdentified ın 21 cases These veıns draınıng the dorsal part of the head opened ınto the dorsal cırcumference of the portal veın In 2 ınstances a ventral veın (Fıg 1 b) draıned the cranıoventral part of the head and ended ın the ventral cırcumference of the portal veın 3 2 and 3 5 cm respectıvely from the confluence These veıns draıned even the cranıal part of the duodenum and probably the pylorıc re gıon (the pylorus was already cut off before radıo-graphy) In 8 ınstances a dorsal pancreatıc veın was observed draınıng the medıodorsal part of the head and endıng ın the dorsal wall of the confluence In 3 cases the dorsal pancreatıc veın was the domınant veın of the dorsal aspect of the head (Fıg 2 a)

In 2 ınstances the dorsal pancreatıc veın formed an arcade together wıth the post ınf pancreatıco-duodenal veın runnıng ın the pancreatıcoduode nal sulcus wıthout changıng ıts calıber (Fıg 2 a) In most cases only smaller collaterals between the post sup and the post ınf pancreatıcoduodenal veıns were observed The post ınf pancreatıco-duodenal veın could be ıdentified ın 9 cases Inser tıon ınto the first jejunal veın was observed ın 6 ınstances ınto the superıor mesenterıc veın ın one



Fig 3

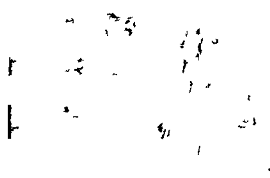


Fig 4

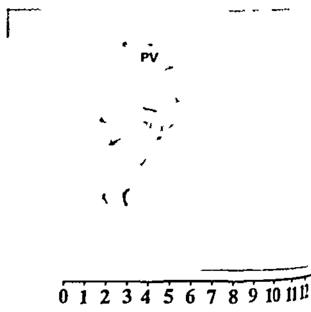


Fig 5

Fig 3 Dorsal aspect of dissected specimen body of the pancreas removed Small post sup pancreaticoduodenal vein (→) dominating post inf pancreaticoduodenal vein (+→) draining to the first jejunal vein

Fig 4 Dorsal aspect of dissected specimen Duplicated post sup pancreaticoduodenal vein (→) Transverse pancreatic vein (+→) draining to the sup mesenteric vein (SMV) near the confluence

Fig 5 Anterior aspect of dissected specimen Pancreatic tissue anterior to the confluence is removed PV = portal vein GCT = gastrocolic trunk Coronary vein (#→) transverse pancreatic vein (+→) Veins of the body draining to the coronary vein (→)

case into the second jejunal vein in one and the post inf pancreaticoduodenal vein was a tributary to the dorsal pancreatic in one The post inf pancreaticoduodenal vein was the dominant vein of the dorsal aspect of the head in one case (Fig 3)

Veins of the body of the pancreas The tiny veins of the pancreatic body were collected in main branches with considerably varying termination The transverse pancreatic vein running along the inferior border of the body of the pancreas could be identified in 16 specimens Its termination was the inferior mesenteric vein in 5 cases the superior mesenteric vein in 3 (Fig 4) the confluence in 3 and the splenic vein in 5

Veins of the body running to the post sup pancreaticoduodenal vein were found in 3 instances the ant sup vein in one

Collaterals to the coronary vein were strated in 8 specimens (Figs 1a 5)

In 2 cases where the pancreatic body was loca cranio-ventrally to the confluence several sm veins drained into the cranial wall of the region the confluence

Veins of the tail of the pancreas drained as a r directly to the splenic vein entering into its trocaudal circumference As the tail of the creas was usually in close connection with ventrocaudal wall of the splenic vein these



a



b

6 Normal phlebography of the head of the pancreas a) Injection into the ant sup pancreaticoduodenal vein Via collaterals filling of the dorsal pancreatic vein (→) the dominant vein of the dorsal aspect the ant inf (↔) and the post inf pancreaticoduodenal vein (⇸) Filling of veins in the hepatoduodenal ligament (⇻) b) Injection into dorsal pancreatic vein almost identical appearance Ant sup (↦) ant inf (↔) and post inf (⇸) pancreaticoduodenal veins and veins in the hepatoduodenal ligament (⇻)

veins were very short and embedded in pancreatic tissue

The number of tail veins draining to the splenic vein which could be identified varied from 3 to 9 (average 6) In cases with a large transverse pancreatic vein which also collected veins of the tail the number of veins draining to the splenic vein were less In one specimen the transverse pancreatic vein was also the main vein of the tail collecting 5 tributaries Two tail veins draining to the lower polar vein of the spleen were demonstrated in 2 cases (Fig 1 b)

The inferior mesenteric vein was identified in all but one case It terminated in the splenic vein at the most 3 6 cm (average 1 8 cm) from the confluence in 15 cases In one specimen the confluence was the point of inflow and in 5 it ended in the superior mesenteric vein at the most 1 5 cm (average 0 9 cm) from the confluence

The coronary vein could be demonstrated in 21 of 22 specimens In 9 cases this vein drained to the cranial circumference of the confluence in 6 cases to the splenic vein within a distance of 2 5 cm (average 1 1 cm) from the confluence and in 4 cases to the portal vein within 2 5 cm (average 1 7 cm) from the confluence In 2 specimens the coronary vein drained directly to intrahepatic portal vein branches of the left lobe

Further observations All main veins of the head and body of the pancreas were observed on the surface of the organ or only partly covered by a very thin layer of pancreatic tissue The veins embedded in the tissue and connecting superficial dorsal and ventral veins were tiny Only the veins of the tail had no or only a short extrapancreatic course

No special interest was paid to the veins of the common bile duct which were often visible at clinical phlebography of the veins of the pancreatic head



Fig 7a



Fig 7b



Fig 8

Fig 7 Phlebography of the body of the pancreas a) Injection into a vein draining to the splenic vein Filling of another vein ending in splenic vein (→) and filling of transverse pancreatic vein (↔) b) Injection into transverse pancreatic vein Filling of the same veins as in (a) and of two veins of the tail (→)

Fig 8 Injection into a vein draining to the splenic vein Collaterals to coronary vein (→) and to post sup pancreaticoduodenal vein (↔)

However in one instance the choledochal veins were dissected Several collaterals existed to ventral veins of the head and to an arcade running along the dorsal pancreaticoduodenal border The veins and their tributaries could be traced to the hilum of the liver (Fig 2b) Collaterals or inflow to intrahepatic portal veins were not observed

Clinical phlebography

Material and Methods

During 1972 to 1978 selective pancreatic phlebography was performed in 140 patients at this Department of Diagnostic Radiology During 1972 to 1974 41 patients were examined using the transumbilical approach to the portal vein Later only percutaneous transhepatic puncture of the portal vein was used

In 61 patients the indication for portography was portal hypertension suggestion of metastatic lesion of the liver or malignancy of the gastrointestinal tract and pancreatic phlebography was performed en passant

In 32 patients the examination was performed for blood sampling and hormone assay In these cases as many veins as possible were catheterized The success rate increased during the period In general at least 4 veins of the pancreas were catheterized in this group

A possible tumour in the region of the pancreas was the indication in 55 patients and selective catheterization was limited to the area of interest usually the head of the pancreas

The technique of percutaneous transhepatic portography is described in detail elsewhere (GÖTHLIN et coll 1974 HOEVELS et coll 1978 REICHARDT &



a



b

g 9 Normal phlebography of the tail a) Injection into a vein of body Filling of veins of the tail Various points of inflow of veins of the tail into the splenic vein (→) b) Injection of a vein of the tail near the hilum of the spleen

GEMANSSON 1980) therefore only a short descrip-
on is given here The puncture was performed with
cm needle coated with a polyethylene catheter
D 1 6 mm ID 1 0 mm Surgimed Denmark) With
catheter in the portal vein a 0 9 mm guide wire
as introduced for further catheterization of the
ncreatic veins The tip of the guide wire was
according to the anatomy and introduced
nto a pancreatic vein The catheter was then pushed
the guide wire into the vein

Phlebography was carried out by manual injection
2 to 10 ml of Isopaque Coronar 370 mg I/ml
Nyegaard Norway) The volume was adjusted to
he size and flow of the injected veins Eight films
were exposed at a rate of 2/s

The catheter should not be allowed to advance nto sub branches in order to obtain a proper filling of the pancreatic and duodenal veins Injection into peripheral tributaries results in incomplete filling and the appearance of the films may mimic and expanding lesion Injection of too large volumes of contrast medium resulted in extravasation in 11 cases

Phlebographic findings

Selective injection of contrast medium into the post sup pancreaticoduodenal vein usually caused filling of the majority of the duodenal branches The ant sup vein was also filled via collaterals in the parenchyma of the pancreas and vice versa (Fig 6) If several veins draining to the portal vein or confluence were present these were also filled by injection into one of them Collaterals to the body of the pancreas were infrequently demonstrated In these instances usually a branch to the main stem of the post sup vein was present Flow of contrast medium from the post sup or ant sup vein to the transverse pancreatic vein was not observed Demonstration of the ant inf or post inf vein by injections into the ant sup or post sup vein was a frequent but inconstant finding probably depending mainly on the size of the inferior veins Veins in the hepatoduodenal ligament with approximately the same diameter as the main veins of the head were not constantly filled In one case an ant inf vein draining to the superior mesenteric vein was catheterized selectively

The right coronary vein was filled by injection into the post sup vein in 4 cases In these instances the right coronary vein had a smaller diameter than the post sup one increasing in size in its course along the minor curvature of the stomach

The shape of the peripheral branches of the duodenal and proximal jejunal veins was usually ampullary

Veins of the body of the pancreas Selective examination of the veins of the body was often difficult to perform as the majority of these veins were tributaries to veins draining other organs (coronary vein inferior mesenteric vein) or to veins of the head of the pancreas The transverse pancreatic vein was easy to catheterize when draining directly to the splenic vein to the superior mesenteric vein

or to the inferior mesenteric vein near its inflow to the superior mesenteric vein or confluence (Fig 7)

Injection into the transverse pancreatic vein usually resulted in filling of the veins of the body positioned to the left of the superior mesenteric vein demonstrating the inflow into the splenic vein and—if present—into the coronary vein (Fig 8) Collaterals to the post sup pancreaticoduodenal vein were filled in a few cases

Selective phlebography of veins draining to the coronary vein was not performed and appears to be difficult due to their position and direction of inflow

Veins of the tail of the pancreas Injection into a vein of the tail usually resulted in the filling of some minor branches and via collaterals the inflow of one or two adjacent veins was demonstrated (Fig 9) Collaterals to the transverse pancreatic vein were observed

The great number of separate veins of the tail draining into the splenic vein was the reason why a complete demonstration of all these veins became a difficult and time consuming procedure in only a few of the present patients appeared the veins of the body and the tail to be demonstrated completely

Discussion

The literature on venous anatomy of the pancreas is limited A detailed description of the venous anatomy of the pancreatic head was given by PETRÉN and of the entire pancreas by FALCONER & GRIFFITHS In the present specimens the main venous drainage of the head of the pancreas was found to correspond closely to these descriptions and their nomenclature was followed essentially The drainage of the posterior aspect of the head by one or several posterior superior veins and drainage of the anterior aspect by the anterior superior vein was an almost constant finding In only one case was the main drainage of the anterior aspect by the ant inf vein and also in one case only was the post inf the dominating draining vein of the dorsal aspect PETRÉN described one case with two post sup veins ending in intrahepatic portal veins Also in the present series the post sup vein could be duplicated and even 3 pancreatic veins terminating in the portal vein were observed Usually the post sup vein ended in the dorsocaudal circumference of the portal vein *Veins inserting ventrally were observed twice* but these veins drained a minor ventral aspect of the head and may represent collaterals to pyloric ve Veins draining to the confluence were called do pancreatic veins in analogy to the arterial nomencl ture Because of lack of experience previousl erroneous conclusion had been arrived at nam that this vein drained the body into the anter aspect of the confluence (LUNDERQUIST & TYL 1975 REICHARDT et coll) In all the present spe mens where a vein draining into the confluence w found it ended dorsally Furthermore all th veins drained the dorsal aspect of the head a should be regarded as a duplication or variation the post sup pancreaticoduodenal vein This co responds to the findings of FALCONER & GRIFFIT who emphasized the fact that despite the close r lationship of the neck of the pancreas to the por vein in no case did a pancreatic tributary enter t portal vein on its anterior aspect This was also tr in the present series regarding the region of the co fluence

In analogy to the arterial nomenclature the v inferior to the pancreatic body (inferior pancre vein FALCONER & GRIFFITHS) was here cal transverse pancreatic vein

Veins of the body of the pancreas may drain any main tributary of the portal vein terminating that region This fact must be considered wh catheterization is performed for blood sampling endocrine tumours Veins draining to the corona vein were relatively common in the present series

The fact that the main veins of the head of th pancreas run on its surface limits the diagnostic va ue of selective pancreatic phlebography in expan ing lesions of the pancreas

The size of exocrine tumours demonstrated b pancreatic phlebography were more than 3 cm in diameter (REICHARDT et coll) This relatively lar size may be surprising but it may be difficult to observe occluded veins inside the gland because of superimposition by normal vessels on the surface of the organ

SUMMARY

The venous anatomy of 22 autopsy specimens of huma pancreas was examined by dissection and radiograph after injection of gelatin agent The most constant finding were the posterior superior pancreaticoduodenal ve draining to the portal vein and the anterior superior pan creaticoduodenal vein draining to the gastrocolic tr nk and superior mesenteric vein Both veins were identified in 21 and 20 of 22 cases respectively All other pancrea

ins varied considerably in their course The normal ndings in clinical selective pancreatic phlebography sed on 148 examinations are described

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COMPENSATORY HYPERPLASIA OF THE HUMAN KIDNEY EVALUATED BY ANGIOGRAPHY AND A DYE DILUTION TECHNIQUE

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Compensatory renal hyperplasia (also called)mpensatory renal hypertrophy) is common after ilateral kidney disease or due to hypo or aplasia the contralateral kidney It is known to occur urly in life (LAUFER & GRISCOM 1971) and in old e (EKELUND & GÖTHLIN 1976) CAVINA et coll 971) performed experiments in dogs which indi ited that the arteries of the hyperplastic kidneys crease in length and width and that the angio aphic circulation time is reduced An investigation man is now reported

Material and Methods

In 13 patients with aplasia hypoplasia or disease f one kidney (occluded renal artery pyelonephritis nultiple scars staghorn calculus) measurements of he renal blood flow and related variables in the ontralateral kidney were made in conjunction with ilateral selective serial nephroangiography The irea of the kidney of interest in a p projection was always at least 50 per cent larger than that of the ontralateral one Catheters (ID/OD 1 4/2 2 mm) were placed in the renal artery and vein respective y A bolus of 0 3 to 1 0 ml of indocyanine green Cardiogreen Hynson Westcott & Dunning USA) was injected into the renal artery while blood was continuously sucked from the renal vein through a spectrophotometer its deflections were recorded on a straight linear potentiometer writer The analysis of the curves was made by copying them on stiff paper cutting them out and weighing them comparing their weight with that of 100 standard units of the paper The blood flow was calculated according to a modified Stewart Hamilton formula For details of the technique and mode of analysis of the curves see GÖTHLIN & OLIN (1973)

The projected kidney area thickness of the cortex and width of the arteries were measured with compensation for the magnification The blood pressure was measured sphygmomanometrically at the beginning of during and after the blood flow measurements

Results

The results by the dye dilution method and some of those obtained at angiography (thickness of cortex and possible lesions of the contralateral kidney) are summarized in the Table

All kidneys with the diagnosis compensatory hyperplasia had an area that was at least 50 per cent larger than that of the contralateral kidney in 7 kidneys also exceeding the upper normal limit of 91 cm² given by MOELL (1961) In the following normal values according to GOTHLIN & OLIN will be given within parentheses

The mean diameter of the renal artery (RAD) was 7 1 mm range 5 3–9 0 (GÖTHLIN & OLIN 5 5 range 4 5–6 8) The mean cross sectional area (RCA calculated from the diameter of the artery on the films with compensation for magnification) of the renal artery was 39 5 mm range 22 1–63 6 (GÖTHLIN & OLIN 23 8 range 16–36)

The mean kidney area (KA) was 89 cm range 61–123 (in normal patients according to MOELL 70–83 SD 7 3–8 3 depending on whether the kidney was right or left sided male or female) The 5 values above 100 cm² were encountered in 3 patients

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Table

Variables of hyperplastic kidney

No	Sex	Age	Side	RAD	RCA	KA	RBF	RBF/m²	VV	VR	MTT	AT	Cortex	Contralateral kidney
1	M	29	L	8 3	54 0	123	840	465	115	9	8 3	3 9	13	Aplasia
2	F	27	R	6 7	35 1	107	740	455	125	8	9 9	4 0	10	Pyelonephritis
3	M	56	L	7 5	44 1	104	620	350	90	13	8 9	4 7	11	Occluded renal artery
4	F	35	L	7 2	40 7	103	445	260	65	14	8 7	4 3	13	Aplasia
5	M	33	R	7 8	47 8	101	700	440	100	11	8 5	4 0	12	Aplasia
6	F	30	R	7 1	39 6	97	630	355	105	9	10 3	4 6	11	Aplasia
7	F	34	L	6 9	37 4	94	605	340	100	9	10 0	4 1	11	Hypoplasia
8	M	58	R	9 0	63 6	83	495	280	75	12	8 9	4 1	9	Occluded renal artery
9	M	48	L	5 8	26 4	73	530	320	75	16	8 7	4 2	10	Occluded renal artery
10	M	64	R	6 8	36 3	72	580	325	70	19	7 0	4 3	10	Multiple scarring
11	M	55	R	5 6	24 6	68	510	300	80	22	9 3	4 5	10	Carcinoma
12	F	54	L	5 3	22 1	61	585	375	80	20	8 1	4 2	11	Staghorn calculus
n				13	13	13	13	13	13	13	13	13	13	
x				7 1	39 5	89	600	350	89	13	8 9	4 2	11	
SD				1 2	16 4	19	108	68	18	4 6	0 9	0 2	1 2	
SE				0 3	4 6	5 4	29	19	5	1 3	0 2	0 1	0 3	
t				22 1	8 7	17	20	19	18	10 4	36	62	33	

RAD=diameter of renal artery RCA=cross sectional area KA=kidney area RBF=renal blood flow VV=vascular volume VR=vascular resistance MTT=mean transit time AT=appearance time

with aplasia one with pyelonephritis and one with a renal artery occlusion 4 of these patients were below 40 years of age

The mean renal blood flow (RBF) was 600 ml/min range 445–840 (GÖTHLIN & OLIN 465 range 405–525 females around 30 ml/min lower than males) The mean RBF per square meter of body surface (calculated according to the formula of Du Bois) was 350 ml/min range 260–464 (GÖTHLIN & OLIN 265 range 220–365) with no difference between the two small groups of males and females

The vascular volume (VV) was calculated according to the formula VV in ml=RBF in ml/in×MTT in seconds The mean VV was 89 range 65–125 (GÖTHLIN & OLIN 70 range 45–95)

The mean transit time (MTT) was calculated as the time from the start of the injection of dye to the baseline projection of the center of gravity in the cut-out curve (with compensation for the delay in the analysing sampling recording system) The mean MTT was 8 9 s range 7 0–10 3 (GÖTHLIN & OLIN 8 9 range 6 8–11 6) In the present series the deviation from the mean value was smaller than in normal kidneys

The appearance time (AT) of dye in the renal vein was measured as the time in seconds from the start of injection of dye to the point of the first deflection of the potentiometer writer (with subtraction of delay in the analysing sampling recording system) The mean AT was 4 2 s (GÖTHLIN & OLIN 4 range 3 7–4 9)

The vascular resistance (VR) was calculated in peripheral resistance units as mean arterial blood pressure in mmHg divided by the renal blood flow in ml/s The mean value was 13 range 8–22 (GÖTHLIN & OLIN 19 range 11–25)

The mean cortical thickness measured in the thinnest section was 11 mm range 9–13 Reliable normal values are not available in the literature measurement of 20 normal kidneys yielded a mean cortical thickness of 9 mm range 7–11

The linear correlation between the following variables was positive

RAD – VR	r	0 627	t	2 676
KA – RBF	r	0 629	t	2 707
KA – MTT	r	0 658	t	2 917
KA – VV	r	0 601	t	2 628

The r factors are above 0 6 and the t values above 2 0 implying that the correlation is statistically significant though not highly so

At angiography in addition to increased width of the main renal artery increased kidney area and cortical thickness which have already been pre-

oned the width and length of the intrarenal ar ries including the subcortical and cortical vessels -as also increased No obvious abnormality was -bserved in the nephrographic phase The intrarenal ins when demonstrated were wider than normal

Discussion

Compensatory renal hyperplasia (or hypertrophy) according to LALLI (1965) the most common cause f unilateral renal enlargement hydronephrosis be ng the second Compensatory hypertrophy occurs unilateral disease regardless of age (BONER et oll 1972 EKELUND & GÖTHLIN) In dogs after ephrectomy increased volume of the remaining idney increased arterial width and decreased cir ulation time at angiography has been demonstrated AVINA et coll) In the present series increased ze of the kidney and increased arterial diameters ere accordant findings however the circulation me as evaluated by the appearance time of dye in ie renal vein and the mean transit time of the dye as normal The explanation for this discrepancy is obably that due to the larger amount of contrast edium transported through the unilateral dog kid ey per unit time CAVINA et coll were able to etect it at an earlier stage than in normal kidneys he increased RBF in the present series should nainly be attributed to an increase in flow volume as he AT and MTT were within normal limits This ine of reasoning is supported by the fact that the ncrease in width of the renal arteries was propor ionally greater than the lengthening

A slightly positive correlation exists between the VV in ml and the kidney area in cm² and thus to the increase in kidney volume (inferring that the in crease in kidney area to some extent reflects the increased vascular volume) Some degree of correla tion between the vascular volume and the cross sec tional area of the renal artery is to be expected as in normal kidneys (GÖTHLIN et coll 1973) The reason why the correlation in the present series is only slight may be that the material is small or that the enlarged kidneys in several of the patients to some extent also were diseased despite absent angio graphic evidence of disease In diseased kidneys no correlation between RCA and VV has been dem onstrated (GÖTHLIN et coll)

No positive linear correlation was found between the diameter or cross sectional area of the renal artery and the area of the hyperplastic kidney WOJTOWICZ (1967) reported some degree of correlation to exist between these variables in renal hyper trophy however not of a positive linear type The mean total renal blood flow in the present series was definitely higher than normal 350 ml/m² as com pared with a normal mean of 265 ml/m² Glomerular filtration and tubular secretion are more or less de pendent upon renal blood flow The RBF thus to some extent reflects the increased function of the hypertrophied kidney which is known to occur (KROHN et coll 1966 LARSSON et coll 1975)

Bearing in mind that the groups are small it is interesting to note that the distribution of RBF/m values is similar in males and females This may be merely coincidental however RBF/m is likely to offer a better means of interindividual comparison than does total RBF because of the wide variation in body size

The cortical thickness is difficult to measure In the present series the thickness was increased over that of normal control kidneys With a special an giographic technique (HEGEDUS 1972) it is possible to quantitate the volume of the cortex In most cases it corresponds to an increase in the thickness of the cortex A correlation has been reported between the cross sectional area of the renal artery and the cor tex volume and vascular volume (GÖTHLIN et coll) and between an increased cortex volume with the ensuing longer and wider vessels and the function of the cortex (KROHN et coll LARSSON et coll) All these variables reflect the increased function of the cortex in the kidney with compensatory hyperplasia

The linear correlation between RBF and VR im plies a lower peripheral resistance in cortical ves sels probably widened The arteries demonstrated at angiography are comparatively large and do not to a great extent influence the resistance thus a change in VR is plausibly elicited distally to the angio- graphically demonstrated arteries Short circuits as the cause of a decrease in peripheral resistance are not compatible with the normal appearance time and mean transit time

In conclusion compensatory hypertrophy of the kidney is characterized by (1) increase in renal blood flow kidney area (inferring also increased volume of the kidney including the cortex) renal artery diameter and vascular volume all reflecting an increased function of the kidney (2) decrease in the vascular resistance and (3) normal circulation time of the blood through the kidney increased flow volume and probably also increased flow velocity

SUMMARY

The renal blood flow and related variables were assessed with a dye dilution technique in conjunction with angiography of the enlarged kidney in 13 patients with unilateral disease hypoplasia or aplasia of one kidney The total renal blood flow the width of the arteries the kidney area the vascular volume and the thickness of the cortex were all increased The vascular resistance was decreased The circulation time through the kidney was normal but the flow volume and most likely also the intra renal flow velocity were increased

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BALLOON CATHETERS

In vitro experiments on pressure influence and risk of rupture

K JEKELL N E PETTERSSON and S SANDQVIST

Balloon catheters have been used in angiography for more than three decades NORDENSTRÖM (1962 1966) elucidated the clinical applications of balloon catheters JENSEN & OLIN (1972) in animal experiments demonstrated that with the use of balloon catheters angiographic results can be achieved which are impossible to obtain with ordinary catheters However balloon catheters have not been used extensively probably due to technical difficulties and risks JENSEN & OLIN (1979) reported that in animals balloon catheters may damage arteries and STRAUBE (1968) also in animal experiments found balloon rupture within a blood vessel When balloon catheters are used in order to control haemorrhage or to diminish the blood flow in highly vascularized tumours injury to blood vessels caused by the catheter can be accepted if this treatment is of vital importance When used for diagnostic purposes higher demands as to safety must be required The risk with the balloon catheter technique appears to be considerable a fact not sufficiently emphasized previously The aim of the present in vitro experiments was to evaluate the risk in two respects (1) the forces exerted on the walls of a tube in which the catheter is inflated and (2) under what conditions rupture of the balloon occurs

Material and Methods

The experiments were made with single lumen balloon catheters The catheter lumen was directly connected with the balloon i e through side holes in the catheter The balloons were inflated with water either placed inside plastic tubes or free in the air The volumes of the balloons were measured at the time of occlusion of the tube and at rupture In connection with the dilatation of balloons inside the plastic tubes the pressure in the balloons (the intraluminal pressure) was measured and also the pressure exerted by the balloon on the tube wall (the lateral pressure)

The catheters were made of polyethylene and the external diameter was 2 8 mm The balloon material was latex rubber its elastic properties are given in Fig 1 The balloons (manufactured by Nordiska Latex AB Torekov Sweden) were made of latex cylinders with an inner diameter of 3 0 mm and a length of 8 mm The wall thicknesses of the balloons were 0 1 0 3 or 0 5 mm Some experiments were made with fusiform latex tubes with a wall thickness of 0 1 mm and a length of 20 mm The balloons were inflated at a rate of 20 ml per minute

The plastic tubes were made of transparent acrylat with inner diameters of 9 15 and 23 mm

The pressure was recorded with a Mingograf with two amplifiers EMT 311 Two Statham pressure transducers model P 23 DB were used measuring pressures up to 160 and 173 kPa (1 kPa=7 5 mm Hg) The intraluminal pressure was measured inside the catheter and the lateral pressure as illustrated in Fig 2 The volume or pressure figures presented are mean values of at least 3 measurements

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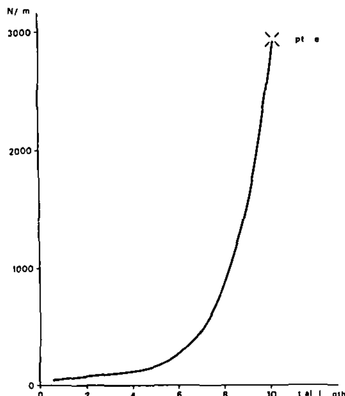


Fig I Elastic properties of latex balloons used in the experi ments

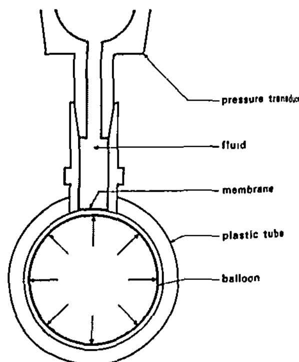


Fig 2 Apparatus for measuring lateral pressure

Results

When a balloon catheter is inflated inside a tube two stages are of importance (1) when the tube is occluded i e when the shape of the balloon is trans formed from a sphere to a cylinder and (2) when the balloon is at the point of rupture The balloon volume at (1) is called ideal and at (2) maximum *volume (Table 1)*

The maximum volume of a balloon is smaller in side a tube than free in air and is reduced consider ably in a narrow tube The volume difference be tween ideal and maximum balloon volumes de creases when the diameter of the tube is diminished

The friction properties of the tube wall play important part when the inside of the tubes treated with silicone lubricant the maximum volu of the balloon was increased by approximately per cent The length of cylindrical latex tubes critical When tubes of great length were inflate only a short segment of the balloon was dilated first The dilated segment rolled over the rest of the balloon thereby hindering further inflation by compression of the undilated part of the balloon When the balloon was made of a fusiform latex it was also possible to dilate long balloons

Table 1

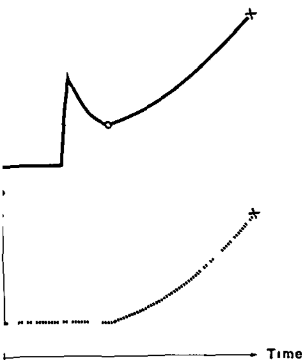
Expansion capacity of balloons free in air and inside plastic tubes a = ideal and b = maximum volume (ml)

Wall thickness *of balloon* (mm)	Volume (ml) of balloon *in air*	Tube diameter *9 mm*		*15 mm*		*23 mm*	
		a	b	a	b	a	b
0 1	30	1 0	1 5	3 0	6 0	7 5	13 0
0 3	3?	1 0	2 0	3 0	7 0	7 5	–

Table 2

Lateral pressures (kPa) of balloons inside plastic tubes c = lateral pressure at ideal volume and d = lateral pressure at maximum volume

Wall thickness of balloon (mm)	Tube diameter 9 mm		15 mm		23 mm	
	c	d	c	d	c	d
0 1			12	51	>0	I
0.3			77	139	13	1
			40	>173	–	



3 Intraluminal pressure (——) and lateral pressure (– – –) asured simultaneously during inflation of balloon within a)e O balloon reaches tube wall × balloon rupture

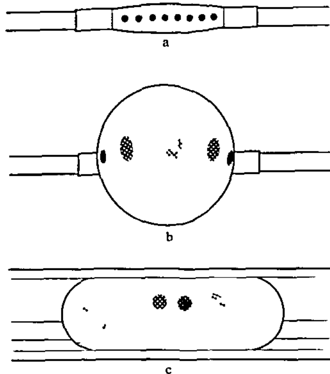


Fig 4 Inflation of balloon marked with equidistant dots of the same size a) Uninflated balloon b) inflated balloon free in air c) inflated balloon inside tube

The lateral pressures at ideal and maximum bal on volume appear in Table 2 Typical curves of traluminal pressure and lateral pressure are illus ated in Fig 3 The highest lateral pressure over 73 kPa was obtained immediately before rupture of balloon with a 0 5 mm membrane thickness in the 5 mm tube With a balloon of a membrane thickness f 0 1 mm in the same tube a highest lateral pressure f 51 kPa was obtained

The relationship between the intraluminal pres ure and the lateral pressure is given in Table 3

Table 3

imultaneous measurement of intraluminal and lateral pressure kPa) on inflation of balloons inside plastic tubes e=intralumi nal pressure and c=lateral pressure at ideal volume

Wall thickness of balloon mm)	Tube diameter					
	9 mm		15 mm		23 mm	
	e	c	e	c	e	c
0 1	37	79	16	17	16	≥0
0 3	91	71	39	77	37	1 3
0 5	–	–	91	40	–	–

only one measurement

The mode of stretching of the balloon wall by inflation inside a tube can be demonstrated by mark ing the balloon with equidistant dots of the same size (Fig 4) When the balloon is inflated free in air the greatest expansion and thereby the greatest increase of size of the dots occurs in the mid section of the balloon If the same balloon is inflated inside a tube the dots increase in size only as long as the balloon does not touch the tube wall Since the mid section of the balloon reaches the tube wall first the dots increase in size in this part of the balloon less than at *the ends where the distension is not hindered*

Discussion

The maximum volume of the balloons is smaller in narrow than in wide tubes This is due to im mobilization of part of the balloon wall that occurs when the balloon is inflated and reaches the tube wall In a narrow tube a great part of the latex mass of the ballon is immobilized already when a small volume is injected As a consequence the intralumi nal pressure will increase quickly and the tension at the free ends of the balloon will soon reach the rup- ture limit of the material The high pressure values in tubes with small diameters can be explained by

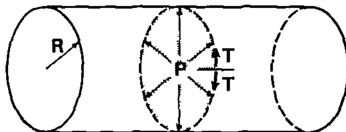


Fig 5 Relation between tension (T) pressure (P) and radius (R) in cylindrical balloon (law of Laplace) T=P×R

the law of Laplace (Fig 5) As the tension in the part of the balloon wall immobilized against the tube cannot increase during further inflation the increasing intraluminal pressure is transmitted to the tube wall i e the lateral pressure The difference between the intraluminal pressure and the lateral pressure at a point at random in the contact surface between balloon and tube is therefore equal to the intraluminal pressure in the balloon when it reaches this point

The discussion raises the questions whether (1) the intraluminal pressure indicates the lateral pressure (2) the intraluminal pressure indicates a risk of rupture of the balloon (3) a suitable size of the balloon in relation to the diameter of the tube minimizes the risk of high lateral pressure and simultaneously reduces the risk of balloon rupture and (4) the risk of high lateral pressure and balloon rupture is minimized by giving the balloon a valve function

Ad (1) The lateral pressure can be determined by measuring the intraluminal pressure at the moment the balloon reaches the tube wall When this pressure is known the difference between the intraluminal and the lateral pressure is also known and the lateral pressure can be calculated It is difficult to determine when the balloon reaches the tube wall if the procedure is controlled by the eye the determination of the pressure is then uncertain

When the balloon reaches the tube wall and its spherical shape is transformed to a cylindrical one a change of slope on the pressure curve occurs This change of slope is observed only when the inflation of the balloon occurs inside the narrowest tube diameter 9 mm On pressure curves from balloon inflations in 15 or 23 mm tubes a change of slope does not appear Thus intraluminal pressure curves can be used for measurement of the lateral pressure only in certain cases

Another method for determining the intralum pressure at the moment the balloon reaches the t wall would be its calculation from the propertie the balloon material the dimensions of the ballo and the diameter of the tube Several mathema models concerning inflation of balloons have b described (TAYLOR & GERRARD 1977) all b valid only when the relative change of the radiu the balloon is very small This is not valid balloon catheters the radius of the uninfla balloon normally being increased several time the occlusion

Ad (2) If the radius of the tube is known the t sion in the balloon wall can be calculated by the of Laplace The maximum tension of the bal material is supposed to be known It is then poss to determine the intraluminal pressure that sh not be exceeded without risk of rupture The hig permitted intraluminal pressure (P_{max}) can be c lated with the same degree of certainty as the by which the radius of the tube is estimated thus underestimation of the radius by 30 per cent ca an overestimation of P_{max} of 30 per cent

Ad (3) The risk of high lateral pressure is smal when a balloon is inflated in a wide tube (Table The difference between ideal and maximum ball volume in such a case may be small resulting rupture already at low intraluminal pressure

The resistance to rupture is greatest when balloon is inflated in a narrow tube When the tu restricts increase of the balloon diameter the tens in the free ends of the balloon first reaches criti values at high intraluminal pressure At the sa time a high lateral pressure is reached

Thus there is a reverse relation between the de mand of protection against high lateral pressure that of avoiding rupture of the balloon The choi of balloon size must be a compromise where the tw factors are weighed against each other

Ad (4) Balloon catheters with single lumen end hole have a valve function The use of cathe of this type involves great difficulties of ball The inflation of the balloon must begin with a h initial injection pressure to dilate the balloon th the pressure must be decreased in order to keep the inflation constant If the inflation is made by h and under eye control the injection pressure can varied as desired On the other hand if the inflati

made with an injector with constant injection pressure the balloon may be overinflated with risk for high lateral pressure and rupture Injections with constant high injection pressure were successful only when the tube had a diameter of 9 mm as the balloon is then very resistant to rupture However this could only be achieved at the price of a high lateral pressure In wider tubes it was possible to obtain the necessary variation of the injection pressure by using two injectors With the first injector a small volume was injected with a pressure high enough to inflate the balloon The inflation was then continued by the second injector at a lower pressure which was adjusted so that the balloon volume was constant

The difficulty of balance can be avoided by the use of a single lumen catheter with a balloon of such size that the amount of contrast medium necessary for diagnostic purposes is small in comparison with the balloon volume The inflation consequently can be made at high pressure and continued inflation of the balloon is tolerated during the short time the diagnostic injection is given (STRAUBE & DOTTER 1963) This method reduces the risk of rupture but may result in a high lateral pressure

Balloon catheters with single lumen with pressure related valve function can be made by giving the balloon calibrated exit holes This type of catheter worked excellently in certain cases while in others rupture occurred even at low injection pressure KERBER (1976) described injections in patients with single lumen catheters with a reinforced hole in the balloon He points out that the risk of balloon rupture exists if the injection pressure is too high A functionally acceptable technique for injection with balloon catheters with valve function has not been found in the present experiments

Clinical applications Balloon catheters are used clinically to occlude blood vessels from the size of the aorta to that of small arteries in the brain (SERBINENKO 1974) The dimensions of the plastic tubes used in the experiments corresponded to dimensions of main arteries BURTON (1951) gave an account of the tension in the wall of blood vessels of different dimensions at normal blood pressure Thus in an artery with a diameter of 10 mm the tension in the vessel wall is 60 N/m In the plastic tube with approximately the same diameter (9 mm) a lateral pressure of 29 kPa was caused by the 0 1 mm balloon at ideal volume This pressure corresponds to a tension in the tube wall which is about 2 5 times as high as that in the wall of the artery When the balloon was inflated to maximum volume a lateral pressure of 165 kPa was reached This pressure corresponds to a tension in the tube wall which is more than 13 times as high as that in the artery at normal blood pressure

The lateral pressures measured during the present experiments cannot be directly applied to physiologic conditions In blood vessels a movement may occur between the balloon and the glossy intima of the vessel Thereby the lateral pressure is reduced as when the plastic tubes were treated with a lubricant In addition the vessel walls are elastic and unlike the plastic tubes distend on increasing the balloon pressure causing a decrease of the lateral pressure The elastic properties of the blood vessels vary The diameter of the vessel and the age of the patient also play an important role Veins have great elasticity and can be distended considerably Atherosclerotic arteries have very little elasticity and even a small dilatation may cause irreversible damage to the vessel

Even if the lateral pressures in vivo are lower than during the experiments it must be considered that balloon catheters may cause dangerously high lateral pressures JENSEN & OLIN (1979) showed in animal experiments that arteries with a diameter of ≥4 mm cannot be dilated more than 20 per cent without injury to the walls

Balloon rupture should not only be considered as a technical complication during angiography but also as a medical risk When a balloon ruptured during the experiments fragments of latex were often torn off An intravasal rupture of a latex balloon may thus cause rubber emboli

Conclusion

A continuous recording of the intraluminal pressure makes it possible to estimate the highest conceivable lateral pressure since this is always lower than the intraluminal pressure If the intraluminal pressure is not allowed to exceed an acceptable level for the lateral pressure harmful lateral pressures can be avoided

The risk of balloon rupture can be reduced by determination of the pressure at which rupture occurs preferably with the balloon free in air This procedure means extra safety because the balloon will rupture at lower pressures than when contained in a vessel

In order to avoid high lateral pressure and balloon rupture the following factors must be known (1) the ideal volumes of balloon catheters in vessels with different diameters so that a suitable balloon size and inflation volume can be chosen (2) the highest permissible lateral pressure in the vessel to be injected (3) the intraluminal pressure at the time of rupture of the chosen balloon free in air The intraluminal pressure must not exceed the pressure levels given under (2) and (3)

Balloon catheter technique is a valuable tool in angiography but the risks involved must be considered significant and difficult to handle Those who use balloon catheters must be aware of the specific mechanical problems connected with catheters of this type

SUMMARY

Balloon catheters with latex balloons were inflated in plastic tubes of different diameters The volume at rupture of the balloons was measured The pressure inside the balloon and that caused by the balloon against the tube walls were recorded Measures to avoid high pressure on the vessel wall and balloon rupture are discussed

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IDIOPATHIC HYPERTROPHIC SUBAORTIC STENOSIS

I Interventricular septum during the systolic contraction

G KVAM

A The shortening of the muscular interventricular septum

Idiopathic hypertrophic subaortic stenosis (IHSS) also referred to as asymmetric septal hypertrophy \SH) hypertrophic cardiomyopathy with or with it obstruction hypertrophic obstructive car iomyopathy muscular subaortic stenosis and symmetric ventricular hypertrophy (GLICK & RAUNWALD 1977)

Disproportionate hypertrophy of the interven ricular septum is the diagnostic feature of the dis ase (HENRY et coll 1973) although not absolutely pecific (WIGLE & SILVER 1978) The septal dimen ion can be measured on echography (SHAH 1977) However disproportionate septal hypertrophy is iot pathognomonic as it may also occur in patients vith concentric hypertrophy and in some normal ubjects

IHSS is a genetically transmitted disease affecting ooth sexes It may be asymptomatic Patients with ymptoms may or may not have subaortic obstruc ion CLARK et coll (1973) observed at echography hat septal hypertrophy was present in 48 per cent of parents in 55 per cent of siblings but in only 30 per ent of children of the patients and concluded that the disease is inherited as an autosomal dominant trait with a high degree of penetrance The reason for the discrepancy between the observed rates in children and among the other relatives is probably that in patients genetically destined to have the disease septal hypertrophy is not always present in childhood but develops gradually and is detected at echography only in later years However they do not exclude that the reason might be technical dif ficulties when examining the children

The disproportionate septal hypertrophy of IHSS is combined with normal sized or small ventricular cavities If the thickness of the septum/free wall ratio exceeds 1 3 the most likely diagnosis is idiopathic hypertrophic subaortic stenosis but ABASSI et coll (1973) have required a septum/free wall ratio of 1 5 for the diagnosis of IHSS The normal average value is 0 95 and in hearts with hypertrophy due to other causes the ratio is about 0 98 on the average

ROBERTS (EPSTEIN et coll 1974) found in 40 hearts from patients with IHSS that in all cases the ventricular septum was thicker than the part of the left ventricular wall located directly behind the pos terior mitral leaflet

The free left ventricular wall in IHSS is generally also hypertrophic In patients with subaortic ob- struction at rest or after provocation the left ven tricular wall directly behind the posterior mitral valve is hypertrophic as the rest of the free wall In the nonobstructive form of the disease on the other hand the myocardium is unevenly thickened Thus the portion of the left ventricular free wall directly behind the posterior mitral leaflet is always of nor mal thickness even when major portions of the left ventricular wall may be greatly thickened (EPSTEIN et coll)

The myocardial microarchitecture of the hyper trophic septum is bizarre with fibre disarray and

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cardiac muscle cells coursing in various directions giving a swirling appearance The myocardium has a similar appearance also in other cardiac diseases with probable isometric contraction (BULKLEY et coll 1977 a) Foci of such disarray may also occur in normal hearts (BULKLEY et coll 1977 b)

Also in patients without obstruction myocardial fibre disarray is observed in the free left ventricular wall while in contrast in patients with obstruction the myocardium forming the free wall is more normal (MARON et coll 1974)

HUTCHINS & BULKLEY (1978) describe the left ventricular septal surface as catenoid like convex in *the longitudinal and concave in the transverse direction* They seem to be of the opinion that the septal abnormalities in IHSS are caused by isometric contraction secondary to the tension distribution across the septal surface because of its specific shape

The IHSS left ventricular cavity is distorted by the hypertrophic myocardial masses Generally it has a flattened S shape with reduced depth downwards from the hypertrophic septum to the free wall (EPSTEIN et coll)

When intraventricular obstruction occurs the stenosis is regularly located between the dorsally bulging septum and an anteriorly moving anterior mitral leaflet in the left ventricular outflow tract (ROSS et coll 1966 HENRY et coll 1973) The reason for the systolic anterior movement is probably the shallow cavity outflow tract and malaligned papillary muscles secondary to cavity distortion allowing anterior suction or forward pushing of the anterior leaflet by the blood stream during systole (HENRY et coll 1975) or both in combination

MARON et coll (1978 a) report outflow obstruction due to systolic anterior mitral valve movement in 5 patients with concentric hypertrophy 3 of these without signs of IHSS indicating that this kind of obstruction is not absolutely pathognomonic

Sometimes the intraventricular obstruction may be *midventricular between the protruding muscular* masses which occurs when the hypertrophic process predominates at the midventricular level (FALICOV & RESNEKOV 1977)

The most common symptoms are dyspnoea anginoid pains syncope and left ventricular failure Sudden death may be the first definitive manifestation of cardiac disease (MARON et coll 1978 b) Generally the natural history of IHSS varies with some patients improving some deteriorating and some remaining stable (GLICK & BRAUNWALD)

The intraventricular obstruction in IHSS wh present may change between examinations or n from beat to beat reflecting the dynamic obstruc mechanism This obstruction being related to contraction is subaortic and evolves progressive during the course of each cardiac systole Thu obstruction exists initially but the early sharp terial pressure upstroke falls rapidly as the o tion develops An increased resistance to ventri filling from the left atrium is reflected in an ele ventricular and diastolic pressure A reduced ventricular compliance leads generally to a ju venous pulse with a prominent a wave (ROSS 19

The cardioangiographic appearance has been scribed by BRAUNWALD et coll (1964) COHEN coll (1964) BOURDARIAS et coll (1968) and SIM (1968) The shallow left ventricular cavity in dia is recognized in the 30° right anterior oblique proj tion The hypertrophic septal bulge is also ident by a concave right heart border and regularly als a small concavity cranially on the left heart bord this projection The shallow diastolic left ventri cavity is not so easily recognized in the 60° r posterior oblique position The dorsally protru upper part of the septum in diastole appearing inverted cone together with the anterior mitral let during the streaming in of non contrast co ing blood may however be recognized

In systole the dorsally bulging septum m the anteriorly moving anterior mitral leaflet recognized A concomitant mitral regurgita usually moderate has been reported in slightly than half of the patients

What appears to be a very forceful contract with a high systolic ejection fraction is regul observed in both views GOTSMAN & LEWIS (19 report an average ejection fraction of 0 87 (SD 0 among their patients with IHSS Nevertheless l ly several reports based on echographic measure ments conclude that the interventricular septum *IHSS has a clearly reduced systolic thickening* an therefore is hypo or non contractile (ROSSEN e coll 1974 COHEN et coll 1975 CATE et coll 19 On the other hand they regularly measure an in creased maximum rate of the systolic thickeni of the posterior wall COHEN et coll (1975) and CAT et coll also found increased absolute values for th thickening The increased ejection fraction and th early emptying of a large fraction of the *stroke* v ume in IHSS (HERNANDEZ et coll 1964) is co sequently considered to be effected by extra



Fig 1 Papillary point identification 30° right anterior oblique left cineangiography in a patient with IHSS a) in diastole and b) systole and a control patient c) in diastole and d) systole Arrows indicate the upper part of the attachment of the posterior papillary muscle

ous contractions of the free wall (COHEN et coll 1975 CATE et coll)

Starting an exploration of the systolic contraction process in IHSS a cardioangiographic analysis of the degree of shortening of the interventricular septum is now reported

Materials Methods and Results

Left ventricular cineangiographies in the 30° right anterior oblique projection at 75 frames per second from 4 IHSS and 15 control patients were analysed

The 4 IHSS patients all males and aged 24 to 64 years had a subaortic chamber with gradients regis

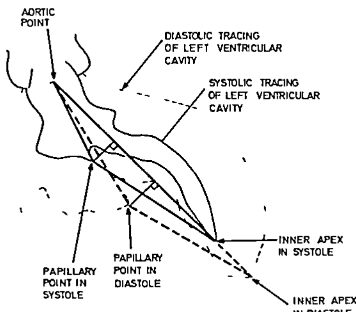


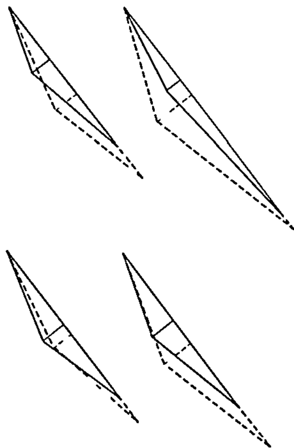
Fig 2 Composite drawing of the outline of the ventricular cavity of a patient with IHSS in diastole (dashed line) and in systole (solid line) It demonstrates how the diastolic and systolic triangles were drawn (thick dashed and thick solid lines respectively)

tered at rest from 35 to 130 mmHg All had eleva left ventricular end diastolic pressure 3 of the negligible mitral regurgitation

The control patients were 7 males and 8 fem aged 23 to 64 years, examined because of ang pain but with normal coronary angiography and no elevation of the left ventricular end dias pressure

The cardioangiographic appearance in the IH group was characteristic In the control group t left ventricle appeared normal in all the patie without abnormal contractions

In every patient a heart beat not preceded b extrasystole was analysed An end diastolic subsequent end systolic frame were identified T end diastolic frame chosen had the largest obser area of the left ventricular cavity before any con tion could be observed Correspondingly the e systolic frame was identified as the one with smallest observed area of the left ventricular ca



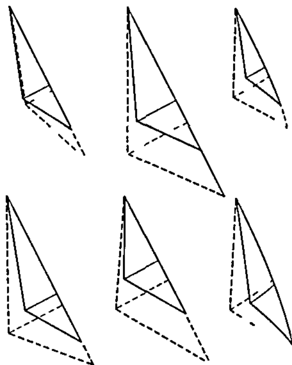


Fig 3 The composite diastolic/systolic triangles drawn a) from the 4 patients with IHSS and b) from 6 controls The diastolic and systolic heights are also drawn The orientation of the tria gles relative to the ventricular cavities are as shown in Fig

Table

Analysis of the composite diastolic/systolic triangles from patients with IHSS and from the controls Significance is at the 0 1 per cent level

	IHSS group	Control group	Significant difference
Apico papillary distance Systolic shortening	0 058 Range 0 04?–0 155 SD 0 096	0 ?57 Range 0 083–0 429 SD 0 084	Yes
Papillo-aortic distance Systolic shortening	0 235 Range 0 081–0 390 SD 0 127	0 185 Range 0 032–0 274 SD 0 0729	No
Apico-aortic distance Systolic shortening	0 137 Range 0 048–0 203 SD 0 068	0 188 Range 0 08?–0 250 SD 0 061	No
Height Systolic shortening	*0 190* Range 0 186–0 609 SD 0 068	*0 318* Range 0 018–0 565 SD 0 128	No
Diastolic height As fraction of diastolic apico aortic distance	0 102 Range 0 012–0 156 SD 0 064	0 255 Range 0 170–0 330 SD 0 050	Yes
Systolic height As fraction of systolic apico aortic distance	0 089 Range 0 013–0 140 SD 0 06?	0 212 Range 0 156–0 279 SD 0 046	Yes
Lengthwise papillary point movement *Distance between heights divided by* diastolic apico-aortic distance	0 109 Range 0 053–0 20? SD 0 068	0 102 Range 0 036–0 191 SD 0 050	No
Lengthwise papillary point movement Distance between heights divided by systolic apico aortic distance	0 130 Range 0 060–0 ?45 SD 0 086	0 127 *Range 0 032–0 217* SD 0 063	No

fore any ventricular dilatation could be observed he upper part of the attachment of the posterior ipillary muscle (papillary point) was identified both diastole and in systole (Fig 1) The inner apex id the middle of the aortic ring were also identified oth in diastole and in systole Diastolic and systolic iangles were measured (Fig 2) The systolic trian les were drawn on top of the diastolic with the ntres of the aortic ring exactly on top of each ther *with the systolic and the diastolic* aorto-apical ne running in the same direction Normals were rawn from the systolic and the diastolic papillary oints to the common apico aortic *line (Fig 3)* These normals were called the systolic and diastol c heights of the ventricular cavity These heights as vell as the distance between them were measured

The systolic shortening of the sides of the trian les and of the cavity height was calculated by divid ng the difference between the diastolic and systolic neasured value by the diastolic one thus Systolic shortening = $(l_d - l_s)/l_d$ where l_d = diastolic meas ured value and l = systolic measured value

The diastolic height was calculated as a fraction of the diastolic apico-aortic length The corresponding systolic height to apico aortic length fraction was also calculated

The distance between the diastolic and systolic heights which reflects the movement of the papil lary point in a direction along the apico aortic axis was calculated as fraction both of the diastolic and of the systolic apico-aortic lengths These values expressed as mean values range of values and stan dard deviation for the two groups of patients are given in the Table An obvious difference exists between the registered apico papillary shortening in *the two* groups The probability that the apico papil lary shortening in the 4 IHSS patients come from the same population as the control apico papillary val ues *is less than 0 1* per cent assuming normal dis tribution

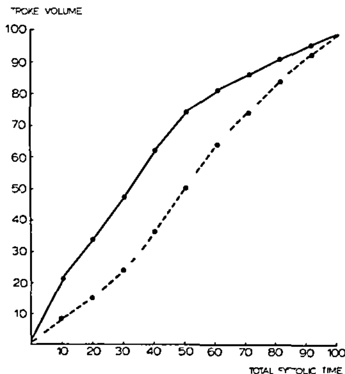


Fig 4 Percentage of total stroke volume ejected during the systolic time span expressed as percentage of total systolic time elapsed Interpolated average values — IHSS group Control group

A difference between the heights of the ventricular cavity also exists expressed as a fraction of the apico aortic distance both in diastole and in systole as significant as the other difference mentioned

No clear difference between the other measured parameters was found (cf the Table)

In each patient the relative ventricular volume was measured according to the area length method (KASSER & KENNEDY 1969) from the end diastolic and the end systolic frames The systolic ejection fraction was calculated $EF=(V_d-V_s)/V_d$ where V_d=relative diastolic volume and V_s=the corresponding systolic ventricular volume In the IHSS group EF averaged 0 85 (range 0 82–0 88) while in the control group EF averaged 0 69 (range 0 63–0 79) Three of the IHSS patients had only a very slight mitral insufficiency Thus no significant calculation error is made by equating left ventricular volume reduction to the amount of blood passing through the aortic valve

The ventricular relative volume was also measured for every third frame between the end diastolic and end systolic frames From these relative volumes and from the number of systolic frames the fraction of the stroke volume passing through the aortic valve by every 10 per cent of systolic time was calculated by interpolation Mean values at every systolic time interval were calculated and t mean values are presented as systolic ej curves for the IHSS patients and the control p respectively (Fig 4)

At all systolic time intervals between the st the end of systole a larger mean fraction of stroke volume had been ejected in the IHSS p When half the systolic time had passed the I patients had ejected an average of 74 per cent o stroke volume (range 67–81 %) The corres mean value among the controls was 50 per (range 42 5–57 %)

Discussion

The difference between the height of the ca is merely a reflection of the well known septal r tation of the left ventricle in IHSS (BRAUNWAL coll)

The posterior papillary muscle arises from posterior ventricular wall close to the groove tween the muscular septum and the posterior The hypertrophic septum of IHSS impinges this region of the posterior wall as can be o from the indentation deformity Non or hy tractility of the muscular septum will rest movement of this region of the posterior wall systole The degree of systolic shortening apico papillary distance is most probably an i but reliable assessment of lengthwise septal s ing during systole The individual values for systolic shortening were −0 042 −0 005 +0 and +0 155 in the IHSS group The reason for t negative values probably is that the walls of t ventricle encroach upon each other in late sy resulting in a twisting of the ventricular geom when the contractile posterior wall drags the a upwards using the bulging septum as a hyp chlion Because of the patient position in relati the longest axis of the heart the effect of this differ from patient to patient In some it will re in overestimation of the systolic shortening others the effect will be the opposite that a r lengthening of the apico-papillary distance d systole occurs is unlikely On this basis the systolic shortening of the apico papillary dista the IHSS group supposedly lies somewhere cl the observed value but the individual data give overestimation of the deviation from this value There seems to be no reason for a si systematic error of observation in the control g These considerations do not invalidate the sta

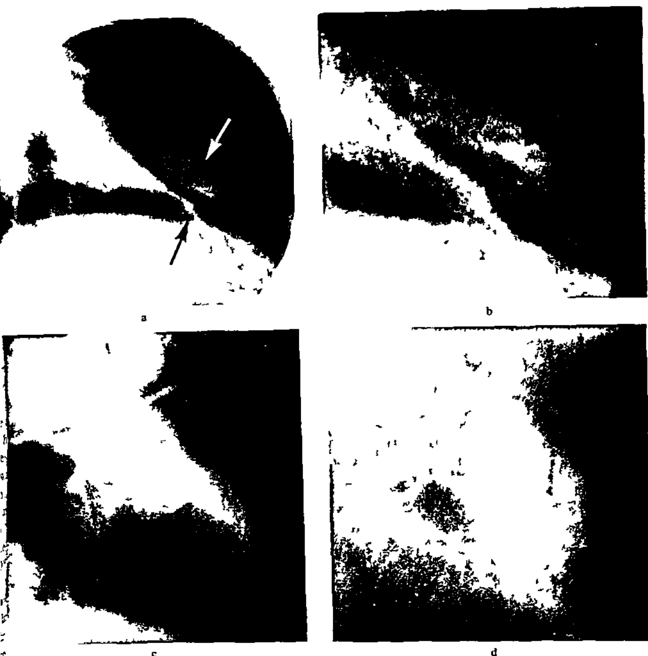


Fig 5 Late systolic lateral tapering of left ventricular cavity in IHSS 30° right anterior oblique view from 2 patients The arrows indicate the outer limits of visible contrast medium a) Streaked lateral tapering between the muscle bundles b) Magnification c) Lateral tapering with a more homogeneous appearance d) Magnification

evaluation given concerning the difference between the groups because in the relevant calculation the number of patients and the arithmetic mean value of the IHSS group were used and the arithmetic mean should be approximately correct

It was shown that the IHSS septum shortens 6 per cent on the average in the longitudinal direction which must be compensated for by an increase of 6 per cent in thickness if the septal volumes is to remain constant

An average systolic increase in septal thickness from 9 3 to 22 5 per cent in IHSS has been reported (ROSSEN et coll COHEN et coll 1975 CATE et coll) If the order of magnitude of these observations is correct the septum cannot shorten much transversely

This can be observed as a lateral tapering of the ventricular cavity towards the end of systole As the relatively non mobile septum does not bend away from the ventricular cavity it acts as a suspender the free wall encroaching upon it during the systolic contraction (Fig 5)

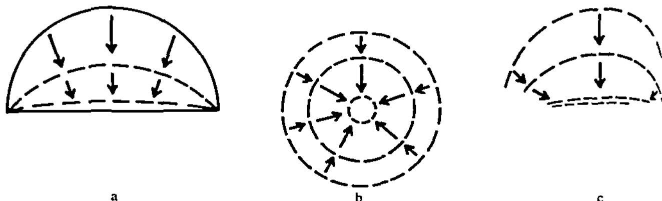


Fig 6 a) Transverse section of a hypothetic left ventricle with semicircular outline flat stiff septum (the diameter) and zero wall thickness When the semicircular free wall contracts from the diastolic phase it changes into a segmental arc The volume (represented by the area) is reduced rather fast the cavity being obliterated when the length of the wall outline is reduced to the same length as the diameter b) Transverse section of a hypothetic left ventricle with circular outline and a concentric contraction The volume is reduced slower relative to the reduction in length of the contractile wall The wall outline must be before the cavity is obliterated c) Transverse sectio hypothetic left ventricle with a semicircular outline m and with zero wall thickness The septum represented astole by the diameter and during contraction by the arc is depicted curved but it does not contract Even duction of the contractile wall length to zero a cons cavity persists

Consequently it may be concluded that the shortening of the septum is markedly reduced also in the transverse direction

The high systolic ejection fraction and the early systolic expulsion of a large part of the stroke volume coincides well with the observations made by HERNANDEZ et coll and GOTSMAN & LEWIS The 4 analysed IHSS patients are representative in these respects

Conclusion The analysis presented supports the views of ROSSEN et coll and others that the muscular interventricular septum in IHSS is non or hypocontractile in the sense that septal shortening is markedly reduced in either direction during systolic contraction

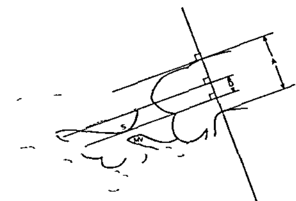
B Analysis of the protruding non bending muscular interventricular septum

HUTCHINS & BULKLEY describe the transverse outline of the IHSS interventricular septum as concave towards the left ventricular cavity Towards the end of systole however a lateral tapering of the cavity occurs only the axial part remaining somewhat more open (Part A) This is most probably due to the fact that contraction of the myocardium around the septal circumference reduces the thickness of the lateral parts of the septum i e by reducing the thickness of the septal attachment This is compensated for by some increase in thickness of the more axial parts of the septum the septal volume remaining constant Thus the left ventricular septal surface loses more and more of its tran concavity during the contraction thereby con ing to the lateral tapering of the ventricular ca

As a simplification the diastolic transvers tion of the IHSS left ventricular cavity may b garded as a half circle the diameter represent septum which the free wall encroaches dur systolic contraction This simplification m allowed as transverse sections of the left ven cavity in specimens from cases with IHSS res half circles the diameter being the septal su the transverse concavity of the septal surfa e quite modest relative to that of the free wall (RER BROWN 1977 HUTCHINS & BULKLEY)

In IHSS a large fraction of the left ven stroke volume is ejected during the first half of tole and the ejection fraction is high The ventricular septum shortens very little Theref has been reasonable to suppose that the fast s volume ejection and the high ejection fract effected by extra vigorous contraction of the left ventricular wall Echography has shown tha increase in thickness of the posterior wall in I occurs faster than normally some authors als port that the increase is greater as well (ROSSE coll COHEN et coll 1975 CATE et coll)

These different aspects represent a geom enigma If the free wall is attached to the edges septum which in principle may be regarded as s flat and immobile and the transverse section of cavity is about half circular calculations show the percentage ex volume per unit myoca shortening is if the contractio



7 Patient with IHSS Composite drawing from which dorsal al movement was measured The aortic width (A) was meas l along a line drawn from above the posterior sinus of Valsal t right angles to the opposite aortic wall The distance (D) veen perpendiculars to this line and tangential to the dorsally ruding septum in diastole (broken line) and in systole (solid) was also measured The fraction D/A was used as estimate orsal septal movement during systole Prolapsing mitral valve /) and dorsally protruding septum in systole (S)

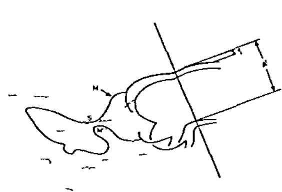


Fig 8 Patient with IHSS Composite drawing from which ventral aortic movement was measured The diastolic and systolic figures were drawn on top of each other as they actually were observed while viewing the cine film The systolic aortic width (A) was measured along a line drawn between two points located just above the diastolic posterior and anterior sinuses of Valsalva. Along the same line the forward movement (f) of the anterior contrast delineated aortic contour during systole was measured The fraction f/A was used as estimate of anterior aortic movement Systolic prolapse of mitral valve (MV) membraneous interventricular septum in systole (M)

icentric This principle is illustrated for the sim theoretic case of zero wall thickness in Fig b

f the septum curved towards the right ventricle ing systolic contraction a practically non short ng septum combined with vigorous contraction the free wall would be easier to understand On other hand a high systolic ejection fraction uld then be rather difficult to account for blood uld collect in a pocket between the contracting e wall and the septum bending towards the right en with a reduction to zero of the transverse di ension of the free wall (Fig 6 c)

An analysis has been performed to find out hether the interventricular septum bends towards e right during the systolic contraction and the sults are now presented

Materials Methods and Results

Films obtained at left ventricular cineangiography the 60° right posterior oblique projection from the male patients with obstructive IHSS and from 10 f the control patients described in Part I were nalysed as cine films had been exposed in the 60° ight posterior oblique position only in 10 (5 men and women aged 23 to 60 years) of the 15 controls The 0° right posterior oblique cine films at 75 frames per econd were obtained simultaneously with the 30° ight anterior oblique cine films analysed in Part A

The end diastolic and systolic frames were identified as the ones with the largest and smallest area respectively Tracings of the inner surface of the left ventricle in systole and in diastole were made as well as of that of the ascending aorta above the sinuses of Valsalva

The tracings were redrawn on top of each other care being taken to draw the diastolic inner anterior aortic border exactly on top of the systolic On this composite drawing a normal was drawn from the inner wall of the aorta just above the dorsal sinus of Valsalva to the opposite wall Perpendiculars to this normal were drawn tangential to the muscular septum in diastole and in systole where it bulged backwards (Fig 7) The distance between these two perpendiculars expressed as a fraction of the diameter of the aorta along the normal drawn first was used as an estimate of the dorsal septal movement

In late systole the aortic root has a slight ventral movement A new composite diastolic systolic drawing was made where the aortic root movement was not compensated for Thus on this drawing the diastolic and the systolic tracings do not correspond exactly A line was drawn immediately cranial to the anterior and posterior diastolic sinus of Valsalva and along this line the diameter of the systolic aorta was measured Along the same line the distance between the anterior inner margin of the aorta in diastole and in systole was measured (Fig 8) The latter distance was calculated as a fraction of the systolic aortic diameter and used as an estimate of the anterior aortic movement during systole



a



b

Fig 9 60 right posterior oblique cine frame from a patient with IHSS a) in diastole and b) in systole Anteriorly bulging membraneous septum (→) with its continuation below in the upper muscular septum The convexity is more prominent than in diastole because of the dorsally moving sep prolapsing mitral valve in systole (↔)

Dorsal systolic movement of the septum in the IHSS group averaged 0 324 (range 0 234–0 453) In the control group the dorsal systolic movement averaged 0 097 (range 0 044–0 177) with SD 0 038

Systolic ventral movement of the ascending aorta averaged 0 081 in the IHSS group (range 0 054–0 104) In the controls the corresponding value was 0 189 (range 0 145–0 250) with SD 0 035

For both parameters the probability that the four IHSS patients came from the same population as the controls was less than 0 1 per cent assuming normal distribution

Discussion

The increased backward/downward movement into the left ventricular outflow tract of the bulging upper muscular interventricular septum is a well known mechanism of the subaortic stenosis in IHSS This systolic movement is quantitated by the method used

The anterior movement of the aortic root during systole is less marked in the IHSS patients than in the controls This is probably related to the dorsally moving and bulging interventricular septum In all 4 IHSS patients in agreement with images and tracings of images previously published by BRAUNWALD et coll and COHEN et coll (1964) the upper anterior margin of the left ventricular outflow anterior bulge in the steep right posterior projection (Fig 9) However this anterior protrusion is an illusion When the anterior systole is put exactly on top of the anterior diastole the systolic upper bulge does not in front of the corresponding diastolic structu upper muscular septum is drawn backwards contracting walls of the left ventricle and th cular septum is in turn dragging the membra septum with it The membraneous septum w attachments in turn keeps a dorsal pull on the root its anterior movement thereby being rest The anterior bulge is formed by the dorsally muscular septum above the most dorsally prot muscular ridge and its continuation into the braneous septum which is pulled anteriorly b aortic root The restricted aortic root mov indirectly implies that the septum does not anteriorly to any significant degree An ante bending muscular septum would not pull the braneous septum dorsally

The shortening of the muscular interventr septum is markedly reduced in IHSS during sy (Part A) and it does not bend during systolic con tion HUTCHINS & BULKLEY have shown tha septal surface is convex longitudinally and con transversely in IHSS They are probably n

posing that the shape of the septum causes an metric contraction Their argument however ts upon assumptions which can hardly be sup- ted They use a model composed of infinitely walled structures (soap bubbles) and with ideal metric surfaces and they seem to believe the ssure distribution across the septal surface to be cause of the isometric contraction However it nore likely that a surface with zero net tension on ner side is the consequence of the forces at work l not the cause of such forces

Therefore an alternative explanation is brought ward The contracting longitudinal septal muscle res tending to straighten out the longitudinal nvexity work against the contracting transverse scle fibres which tend to move the septal surface vards the cavity centre These two contractile nponents of the septum then have the net effect it the contracting IHSS septum is locked in oppos isometric contraction They necessarily balance h other because shortening in one direction etches the myocardial fibres in the opposite direc n therby increasing the opposing force according the Starling principle until an equilibrium is iched and vice versa

The basic defect of the disorder thus most prob- ly is an anomalous shape of the muscular inter ntricular septum as assumed by HUTCHINS & JLKLEY leading to isometric contraction and sec idary hypertrophy of the septum The septal mi ostructural abnormalities are thereby accounted r (WIGLE & SILVER)

Conclusion The analysis supports the idea that e IHSS hypertrophic muscular septum is relatively gid and non bending during systole

The abnormality of the septum is most probably n anomalous form leading to isometric contraction A stiff septum with markedly reduced systolic short ning and with an active myocardial wall attached round it acts as a suspender An ordinary degree of myocardial fibre shortening by the free left ventricu lar wall will expel the stroke volume faster and also give a higher ejection fraction than in an ordinary heart which has a more concentric contraction Whether this explanation is sufficient or whether it is necessary to suppose a more vigorous contrac tion of the IHSS free left ventricular wall in addition in order to explain the high ejection fraction and the fast stroke volume ejection of the disease is open to discussion

Echographic observations certainly seem to support the idea that hypercontractility of the free wall is also involved even though this is not the only explanation In a later communication this problem will be analysed by using cardioangiographically de termined parameters as input in geometric models in order to determine the actual fibre shortening of the free wall of the IHSS left ventricle

SUMMARY

Biplane left ventricular cineangiographies in 4 patients with typical obstructive idiopathic hypertrophic subaortic stenosis (IHSS) and in control patients with normal left ventricles were analysed In the protruding hypertrophic muscular interventricular septum of IHSS a markedly re duced shortening occurs in either direction during the systolic contraction It does not bend towards the right ventricle It is suggested that the septum of IHSS acts as a suspender during the systolic contraction thereby ac counting for the fast stroke volume ejection and the high ejection fraction of IHSS

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RADIOGRAPHY OF THE SMALL INTESTINE WITH LARGE AMOUNTS OF COLD CONTRAST MEDIUM

BIRGITTE BRUN and VIKTOR HEGEDUS

Although numerous methods for radiologic ex ination of the small bowel have been described ing the last half century (PANSDORF 1937 WEIN AUB & WILLIAMS 1949 GOLDEN 1959 MATTSSON coll 1960 SELLINK 1974 1976 MARSHAK & IDNER 1976) no method has been accepted as a ndard procedure and many departments are still need of a simple and rapid method for daily rou e The examination of the small bowel is often rformed as a continuation of a gastric series with relatively small amount of barium contrast me um This method gives only segmental demonstra on of the small intestine and the contrast medium nds to pool after a couple of hours in ileal loops the lower part of the abdomen (Fig 1 a) The dia iostic value of the examination is doubtful and the ansit time is long Little information on the anato y of the small bowel is obtained and the appear ice of the mucosa is seldom demonstrated In addi on the protracted examination is tiring to the pa ent often uninspiring to the radiologist and dis irbs other fluoroscopic work

Forty years ago it was pointed out that the use f large amounts of contrast medium improves the uality of the examination and reduces the transit me (WELTZ 1937) At nearly the same time it was ported that cold fluid leaves the stomach sooner nd passes more rapidly through the intestine than ieals at room temperature (GERSHON COHEN et oll 1940)

Thus a combination of these methods i e the use of a large amount of cooled contrast medium should ive rapid demonstration of the small intestine and films of high quality. However this method does not seem to be universally used (PIERCE personal communication)

Material and Method

During 1976 and 1977 203 examinations of the small bowel with a large amount of cold contrast medium were performed in 170 adults and 33 children Indication for the examination findings transit time and total examination time were recorded Furthermore in 25 patients two examinations were performed with an interval of 1 to 6 years the first one being a follow through after gastric examination at the second one 500 ml cold contrast medium was used The difference in transit time between the two examinations was recorded

Technique Adult patients were given 500 ml Mixobar (Astra Denmark) 1 g/ml in a 30% dilution children somewhat less The contrast medium was mixed with tap water cooled to approximately 5 C After the barium meal the patient was placed in the right lateral position Fluoroscopy was performed at short intervals especially at the beginning of the examination Films surveys and spot films were taken when the various parts of the intestine were well filled The examination was concluded when all segments of the small intestine had been satisfactorily demonstrated The exposures were made at 120 kV

Submitted for publication 16 January 1979





a b

Fig 1 13 year-old girl with ulcerative colitis a) Small bowel examination with a small amount of contrast medium pooling in ileal loops in lower part of the abdomen This film has no diagnostic value b) Almost the entire length of the small bowel demonstrated on one film with a large amount of col medium The filling is uniform and the appearance of the visible

Results

The indications for the examination are given in Table 1 and the findings in Table 2 A diagnosis was reached in 189 patients Well defined lesions were found in 71 cases no abnormalities in 118 The group named others represents a broad spectrum of conditions such as jejunal diverticulosis Meckel s diverticulum sequelae to intestinal tion internal hernia (Fig 2) In 14 patients the amination was incomplete or inconclusive

Six of the 203 examinations were excluded the series either because the transit time or examination time was not recorded or because examination was concluded before the con medium had reached the caecum In the rema 197 cases the transit time to the caecum was than one hour in 56 between 1 and 2 h in 71 between 2 and 3 h in 87 per cent

The examination was completed in less hours in 89 per cent of the 203 cases in 31 per in less than one hour In 118 cases no abnormal were found In this group the transit time to caecum was less than 3 hours in 95 per cent examination was completed in less than 3 hours 93 per cent A comparison of the transit time in 25 patients examined by both the conventi follow through examination and the one with a l amount of cold contrast medium showed that mean transit time was reduced from 267 to 11?

Table 1

Indications for small bowel examination

	No of patients
Malabsorption and diarrhoea	64
Crohn s disease	48
Pain and dyspepsia	38
Gastrointestinal haemorrhage	8
Sub-ileus	22
Abdominal tumour	14
Others	9



a



b

2 43 year-old man with intermittent intestinal obstructions lowed by spontaneous relief since childhood Examination h a large amount of cold contrast medium during an attack ealed a paraduodenal hernia a) A p view Mesenterial mal rotation Air filled small bowel loops in left side of abdomen b) Lateral view Contrast filled ileal loops dorsal in the hernial sac the neck →

Discussion

The aim of a radiologic examination of the small bowel should be the demonstration of the entire length of the jejunum and ileum Contrast filling should be uniform and make it possible to evaluate details in the mucosa Since SELLINK (1974 1976) introduced double contrast examination of the small intestine it has been increasingly realized that his part of the gastrointestinal tract requires just as careful an examination as the stomach and colon SELLINK used a duodenal tube through which large amounts of barium plus water or air were injected This method demonstrates the entire small bowel mucosa excellently and rapidly However a method more comfortable to the patient giving adequate clinical information without duodenal intubation is preferable The large amount of diluted and cooled contrast medium was well accepted by the patients both adults and children

As early as 1937 it was pointed out by WELTZ that the quality of small bowel examination depends upon the degree of filling In recent years MARSHAK & LINDNER in particular have emphasized the importance of large quantities of contrast medium which stimulates gastric emptying and reduces the transit time (CALDWELL & FLOCH 1963 KIM 1968 MARSHAK & LINDNER) The large volume gives uniform filling of the intestinal loops and protects the barium meal from the disintegrating influence of the gastric and intestinal contents The effect of water absorption from the ileum is reduced when the volume of the contrast medium is large and the transit accelerated

Table 2

Radiologic abnormalities

	No of patients
Malabsorption	17
Crohn s disease	13
Adhesions	22
Ascites	2
Space filling lesions	6
Malrotation	2
Others	23



a



b

Fig 3 Two cases of biopsy proven celiac disease a) Flocculation of small amount of barium at follow through examination Evaluation of the mucosa not possible b) The appearance of the mucosa demonstrated with the use of a large amount of contrast medium

Superimposition of small bowel loops may constitute difficulties when a large amount of contrast medium is used By diluting the contrast medium and by the use of high kilovoltage and compression films these difficulties can usually be overcome

GERSHON COHEN et coll found that an ice cold meal leaves the stomach much faster and passes more rapidly through the small intestine than meals at room temperature or heated meals WEINTRAUB in 1941 observed (WEINTRAUB & WILLIAMS 1949) that iced drinks after a meal increased the motility of the contents in the gastrointestinal tract and resulted in diarrhoea After several experiments these authors presented a rapid method for examination of the small bowel They used isotonic saline at room temperature and afterwards ice cold physiologic saline They reported good film quality and a short transit time with this method but drinking this fluid cannot have been pleasant for the patients

In the present series Mixobar was diluted with cold tap water and the patients were given 500 ml of this suspension The contrast medium was easily accepted in this form Mixobar has proved a sta contrast medium which does not flocculate e during long lasting examinations or in cases of m absorption The transit time was considerably duced by changing the barium meal from 250 at room temperature to 500 ml cooled contrast 89 per cent of the patients the examination was co pleted in less than 4 hours However many of the patients had pathologic conditions in the small in testine which per se may increase the transit tim Therefore a group of examinations without abn malities was considered separately In these the total examination time was less than 3 ho in 93 per cent The comparison of the two diagno methods in 25 patients revealed that the use of large amount of cold contrast medium reduced transit time by about one half

From a diagnostic point of view the method sented has also proved an advantage If the amou of contrast medium is too small the barium has tendency to accumulate in intestinal loops whi impossible to identify and thus gives little diagno


a


b

Fig. 4 17 year-old girl with Crohn's disease in terminal ileum and ascending colon. Displacement of intestinal loops indicates extra intestinal extent of the disease.

formation (Fig 1 a) The use of a large amount of cold contrast medium affords uniform filling of the intestinal loops and often makes it possible to demonstrate the entire small intestine on one film (Fig b) Changing the patient's position and the use of compression can disclose even minor abnormalities in the mucosa.

In patients with malabsorption the advantage of the method is obvious (Fig 3) When a large amount of cold contrast medium is used flocculation and segmentation of the contrast medium rarely occur. The intestinal mucosa is well coated with barium and the appearance of the mucosa well demonstrated. Furthermore in patients with localized swelling of the intestinal wall indentations in the surrounding loops indicate the extent of the lesion (Fig 4)

SUMMARY

A rapid method using a large amount of cold Mixobar for radiography of the small bowel without duodenal intubation is presented. The diagnostic value of the method and the transit time were analysed in 203 patients. The quality of the examinations was good. The transit time was reduced compared with conventional methods.

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RADIOGRAPHIC APPEARANCES IN CROHN S DISEASE

III Colonic lesions following surgery

J HILDELL C LINDSTRÖM and A WENCKERT

Considerable interest has been given to analysis of problem of recurrences following operation for ohn s disease (VAN PATTER et coll 1954 COL CK & VANSANT 1960 STAHLGREN & FERGUSON 51 BARBER et coll 1962 ATWELL et coll 1965 ILL et coll 1969 DE DOMBAL et coll 1971 a b OLIGHER et coll 1971 WALLENSTEN 1971 ENCKERT 1971 NUGENT et coll 1973) However attempts have been made to analyse the exist ice and localization of the recurrences in relation both the preoperative distribution of the lesions id the operative methods employed Neither have currence in the small intestine and recurrence in ie colon been considered separately

In previous reports radiographic features of onoperated patients with Crohn s disease were onsidered with special reference to minor lesions Part I HILDELL et coll 1979) The purpose of the resent communication is to describe the postopera ive radiographic appearance of the colon The find ngs are also correlated with the preoperative dis ribution of the lesions the operative procedures mployed and the appearance of the new distal leum

Material and Methods

The same material as in Parts I and II was used (HILDELL et coll 1979) The postoperative films of all patients in whom the disease preoperatively was located in the distal ileum the distal ileum and the colon or the colon alone and in whom the entire or large parts of the colon were left behind at re sectional procedures were reviewed The series con sisted of 317 small and 247 large intestine examina tions performed in 114 patients The postoperative appearance of the colon and the small intestine was recorded and correlated with the preoperative distribution of the lesions and the operative proce dures employed (Fig 1)

Results

Postoperative appearance of the colon

In 86 of 114 patients no abnormality was found In the remaining 28 patients various types of lesions were recorded

Postoperative submucosal edema (12 patients) The patients had no clinical evidence of recurrent colonic disease (Fig 2)

Postoperative colitis (16 patients) a) Superficial fluctuating colitis The patients had no definite clini cal evidence of recurrent disease in the colon (7 patients Fig 3) b) Colitis with clinical evidence of recurrent disease in the colon (9 patients Fig 4)

Comparison between pre and postoperative appearances

Colonic lesions were left behind in 14 patients (D–F Fig 1) The occurrence of postoperative colitis was strongly related to the existence of preoperative lesions in segments left behind at op- eration (Fig 5) Of 16 patients with postoperative colitis 13 had preoperative lesions while in 3 pa tients no relationship with preoperative lesions was

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Radiographic appearance of the new distal ileum and the colon after operation for Crohn s disease

Extent at time of op Op methods	No re current disease	Abnormalities characteristic of recurrence: Distal ileum	Distal ileum and colon	Colon
A 5		5		
B 83	54	26	3	
C 11	6	5		
D 2			2	
E 10	1		8	1
F 2				2
G 1	1			
114	62	36	13	3

Fig 1 Correlation between the extent of disease at the time of operation the operative procedures employed and the postoperative appearance of the colon and the new distal ileum

found More detailed information is given in Fig 6 The different types of postoperative colonic lesions are correlated with the preoperative distribution of the lesions and the operative procedures employed

In the patients with postoperative submucosal edema no correlation with preoperative lesions was found In 3 of the 16 patients with postoperative colitis no correlation with any preoperative lesion was found No preoperative examination of the colon was performed in one of these 3 the second was examined only once The quality of the films was unsatisfactory and possible existence of minor lesions could not be evaluated In the third patient a resection of a kissing lesion in the sigmoid colon was performed in addition to an ileotransverse colostomy In the remaining 13 patients lesions were recorded both pre and postoperatively

Thus in 13 of 14 patients (93%) a relationship existed between postoperative colitis and preoperative colonic lesions while in 3 of 100 patients no such relationship was found The differe[nce was] significant ($p<0.001$)

Postoperative lesions in the small intestine

Different types of lesions were observed in the small intestine (more detailed information will be available in a forthcoming report)

(a) Edema Broadened and irregular m[ucosal] folds but no ulcers and no local progression patients had no clinical evidence of recurrence

(b) Radiographic recurrence Abnorma[lities char]acteristic of recurrence in asymptomatic

(c) Recurrence Radiographic and clinical [evi]dence of recurrence

The two latter groups are referred to as postop[era]tive ileitis

The relationship between postoperative col[onic] lesions and the postoperative appearance of the distal ileum appears in the table

Of 16 patients with *postoperative colitis* 1[?] had a postoperative ileitis Two of these were [oper]ated upon with segmental resection of the ile[um] in Fig 1 VI in Fig 6) and both ileal and co[lonic] lesions persisted postoperatively Another 2 p[atients] (F in Fig 1 VIII in Fig 6) were operated upon [with] resection of the rectum and the aboral colon neither pre nor postoperatively had any ileal [le]sions In the remaining 12 patients a presum[ably] normal ileal segment was operatively conne[cted] with a colonic segment that was postopera[tively] (and in the majority of the patients also preope[ra]tively) involved by colitis In 11 of these 12 pat[ients] (92%) recurrence had developed in the new d[istal] ileum in addition to postoperative colitis

In 31 patients a postoperative ileitis was fo[und in] the ileal segment (Fig 1 B C) that was a[nas]tomosed to a preoperatively normal segment of the colon (3 patients accounted for above being [ex]cluded B in Fig 1 III and V in Fig 6) In no[ne] of these 31 patients was any postoperative co[litis] found

Thus it appears that linear extension of lesi[ons] across an ileocolic anastomosis was significa[ntly] more frequent in oral (92%) than in aboral (0[%]) direction ($p<0.001$)

Also in 12 patients with *postoperative submuco[sal] edema* in the colon a high rate of additional [ileal] lesions existed 7 patients had postoperative ile[itis] and 3 had edema (I + II in Fig 6)


a


b

...an 2 a) Postoperative submucosal edema in the transverse ...on in a patient with an ileocolic anastomosis b) Detail of ...isverse colon

Management of postoperative colitis

Of the 16 patients with *postoperative colitis* 13 ...ere reoperated upon 8 of 9 patients with clinical ...vidence of recurrent colitis and 5 of 7 with superfi...al colitis In 7 of the 8 patients colectomy and ...ostomy was performed None of these patients had another recurrence In the remaining patient the distal ileum was anastomosed with a slightly diseased rectum This patient soon had another recurrence

Of the 7 patients with superficial colitis 5 were operated upon with resection of the new distal ileum and a new ileocolic anastomosis was performed

Table

Relationship between postoperative colonic lesions and the postoperative appearance of the new distal ileum

Colonic lesions	No of patients	Postoperative appearance of the new distal ileum			
		Normal	Edema	Postoperative ileitis	
				Radiographic recurrence	Recurrence
Submucosal edema	12	2	3	3	4
Postoperative colitis					
Superficial	7	1			6
Recurrent	9	2			7
Total	28	5	3	3	17



a



b

Fig 3 a) Postoperative superficial colitis in a patient with ileocolic anastomosis Multiple superficial ulcers in the remaining colon and extensive lesions in the distal ileum b) Deta verse colon Multiple punched out and aphthoid ulcers

The indications were recurrent disease in the distal ileum and the colon was normal to inspection and palpation at operation Microscopy of the resected colonic segments revealed inflammatory lesions All patients had a second recurrence in the distal ileum and the colonic lesions persisted

Two patients of 13 with *postoperative submucosal edema* in the colon were operated upon because of recurrent disease in the new distal ileum In both patients microscopic examination of the resected colonic segments confirmed the radiographic dia gnosis of edema

Discussion

In the literature recurrence of Crohn s disease is accounted for in different ways in regard to both frequency and localization In most reports recur rence of the disease is principally correlated with the operative methods employed and the localization of recurrent disease is not further specified (BA coll ATWELL et coll BRILL et coll DE DO coll 1971 b) Some authors however hav such a specification but have not correla localization of recurrent disease with the pr tive distribution of the lesion of the operative dures employed (DE DOMBAL et coll 1971 a J & VIGNAL 1976)

Still others provide information concerni currence rates correlated with the postoperati tribution of the lesions but further particular cerning operative procedures and localization current diseases are absent (SCHOFIELD 1965 LENSTEN)

In the radiologic literature little has been rep on recurrence of Crohn s disease in the colon authors mention parenthetically that spread c disease to the colon is more common after su intervention than before (BRAHME & WENC 1970 MARSHAK & LINDNER 1970 BRAHME & I



a



b

Fig 4 a) Radiographic and clinical recurrent colitis 3 months after the primary operation Multiple punched-out ulcers in the descending colon Air filled and featureless distal ileum b) Detail of framed area in the descending colon in (a) Multiple punched out ulcers

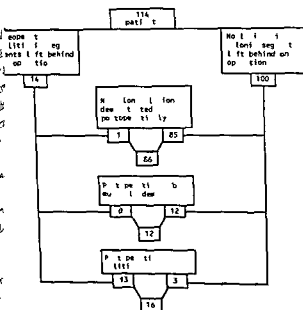


Fig 5 Correlation between postoperative colitis and the preoperative appearance of colonic segments left behind on operation

1975 SIMPKINS 1976) but no attempts have been made at a closer analysis The present results may be summarized as follows

Postoperative findings	No of cases	Preoperative appearance and management
Recurrent colitis	9	Colonic lesions left behind (8) Resection of a kissing lesion (1)
Superficial colitis	7	Colonic lesions left behind (5) No examination of colon (1) Unassessable examination (1)
Submucosal edema	12	Normal preoperative colon (12)

Group and No of cases		Extent at time of op Op methods	Postop colonic lesions	Postoperative lesions in the small bowel: Normal	Edema	Radiogr recur	Recur
I	9			1	3	1	4
II	3			1		2	
III	2						2
IV	5			1			4
V	1						1
VI	2						2
VII	4						4
VIII	2			2			
28				5	3	3	17

Fig 6 Correlation between postoperative colonic lesions the postoperative appearance of the new distal ileum the extent of disease at the time of operation and the operative procedures employed ☐ Severe lesions ☐ Superficial lesions ☐ Submucosal edema

Thus in 8 patients of 9 with *clinical and radiographic recurrence* the colonic lesions existed already preoperatively Therefore the recurrence must be considered to be due to an exacerbation of the disease in segments left behind at operation The ninth patient had recurrence after surgical removal of a kissing lesion in the sigmoid colon The cause of the recurrence in this patient is not clear In the literature only a few authors have touched upon the problems concerning the surgical approach to kissing lesions CHÉRIGIÉ et coll (1973) reported the same experience in 2 patients after resection as was encountered in one patient in the present series SCHOFIELD had in 5 patients 2 recurrences and one operative death This does not prove that there is a causal relationship between resection of a kissing lesion and recurrence of the disease in the colon but the possibility must be considered

A superficial fluctuating colitis was recorde[d] patients postoperatively In 5 of these the le[sions] existed preoperatively and were left behind at [opera]tion In one of the remaining 2 patients no [in]testine examination was performed preoper[atively] and in the other only one which was not e[valuable] with regard to minor lesions In this particula[r form] of the disease the mucosal lesions have a t[endency] to appear intermittently and therefore it is [conceiv]able that the colon in these 2 patients was in[volved] also preoperatively

Hence if colonic lesions were left behind [at op]eration a significantly high risk of postope[rative] recurrence of the disease in the colon existe[d On] the other hand if no lesions were left behind th[e risk] was low no matter whether postoperative l[esions] were found in the new distal ileum or not [Most] probably reports on postoperative spread [of the] disease to the colon (BRAHME & WENCKERT [...] SHAK & LINDNER BRAHME & FORK SIM[...] may be explained by the fact that colonic l[esions] were overlooked at the preoperative exam[ination] and during operation

Submucosal edema is not specific for Crohn['s dis]ease but appears in any type of colitis Its pr[esence] in 12 patients in this series is difficult to eval[uate It] may be representative of the basic disorder [On the] other hand the lesions did not progress whic[h may] indicate that the edema might be a nonspecific [reac]tion to for example diarrhea caused by con[tempo]rary ileal lesions or malabsorption

It is hard to explain the high rate of recurre[nce in] the new distal ileum that was recorded in addi[tion to] postoperative colitis (13 of 16 patients)

One explanation may be that ileal lesions we[re left] behind at operation and hence that the postop[era]tive ileal lesions represented an exacerbation o[f the] disease However considering the results of [opera]tive treatment for recurrent disease this t[heory] seems less plausible After reoperation patients [op]erated upon with colectomy obviously differed [from] patients with a new ileocolic anastomosis I[n the] former patients no further recurrence devel[oped] while in the latter (i e patients with superficial [coli]tis) another recurrence occurred in the new d[istal] ileum in addition to persistent colonic disease

More plausible is that recurrence in the new d[istal] ileum was caused by spread of the disease from [the] colon a spread that was made possible by the op[era]tively accomplished anastomosis This theory i[s fa]vored by the results of operation for recurre[nt]

It should also be mentioned that recurrence [dev]eloped in the distal ileum of several patients (not [incl]uded in this series) after an operative connection [of t]he ileum to a slightly diseased rectum However [if t]his theory is true there is no reason why the [dise]ase should not spread in the opposite direction from a diseased distal ileum to a nondiseased [col]on As is obvious from the results this did not [ha]ppen An explanation for this phenomenon might [be] afforded on the basis of the theory of lymphatic [spre]ad that was postulated previously (Part II) A diseased ileum and a diseased transverse colon [whic]h have their lymphatic drainage through the [sup]erior mesenteric system of lymphatics and the [ile]um has no alternative way of drainage On the [con]trary if a diseased ileum is connected to a non[dise]ased transverse colon this has an alternative [wa]y of drainage through the inferior mesenteric sys[tem] of lymphatics

[W]hatever theory is correct patients in whom co[loni]c lesions are left behind at operation run a high [risk] of developing recurrent disease in the colon and [th]e new distal ileum This is also true in patients in [who]m the mucosal lesions have regressed or the [dise]ase manifests itself only in the form of superficial [muc]osal ulcers The capricious and fluctuating na[ture] of colonic Crohn s disease should always be [bor]ne in mind and temporary healing of mucosal le[sio]ns should not be regarded as permanent healing [If] a patient once has been proved to have lesions in [the] entire colon he should always be regarded as [ha]ving pancolitis The postoperative prognosis is [pr]obably the same whether mucosal lesions are [fou]nd at the time of operation or not

It is obvious that a careful preoperative evaluation [of] the extent of disease is of the utmost importance [Th]e diagnosis of minor mucosal lesions in the colon [ca]nnot be made at the operation as only limited [po]ssibilities for making a true diagnosis of the le[si]ons exist at operation

Consequently the diagnosis of minor mucosal le[si]ons should be made at the radiographic examina[ti]on and the diagnostic radiographic methods by [w]hich these lesions are demonstrable must be used [(P]art I)

SUMMARY

Postoperative films of 114 patients subjected to a pri[m]ary operation for Crohn s disease were reviewed with [s]pecial regard to postoperative lesions in the colon Recurrence in the colon was in 13 patients of 16 due to an exacerbation of the disease in segments left behind at operation Recurrence in the new distal ileum in addition to persistent colonic disease occurred in 11 patients of 12 This was probably due to the operative connection of the ileum to a diseased colon

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RADIOGRAPHY IN PRIMARY TUMORS OF THE SMALL BOWEL

OLLE EKBERG and SVEN EKHOLM

The preoperative diagnosis of tumors in the small wel is still not satisfactory The symptoms of the nor are vague and unspecific and therefore often rlooked by the clinician Consequently the pa nt will not have any proper radiologic examina n (SILBERMAN et coll 1974) These tumors have ow frequency and a correct radiologic diagnosis hought to be rare even on those occasions when tumors are observed on the films (VUORI & JORI 1971) The present investigation was per med to find out the frequency of primary tumors the small bowel and to what extent radiology was nsulted in these hospitals which are referring spitals in Southern Sweden A retrospective aluation was also performed to assess how often correct radiologic diagnosis could be made and the portance of different radiographic methods

Material and Methods

The files of these two hospitals and of other hos itals in the region were reviewed for patients who n operation or autopsy were found to have tumors f the small bowel during a period of 7 years (1971–977) Only tumors of the jejunum and ileum were ncluded The duodenum was omitted because the xamination of this region was felt to be less contro-versial being routinely included in barium examina ion of the stomach It is also possible to explore his region via endoscopy Primary lymphomas of he small bowel have been excluded from the ma terial because of the difficulties in separating them from secondary lymphomas even on autopsy Ex aminations of interest were abdominal survey films barium contrast examinations of the small bowel and angiography

Results

The mean annual number of inhabitants in the area was 1 424 282 A total of 133 confirmed primary small bowel tumors were found which corresponds to a mean annual incidence of 1 33 per 100 000 Of these 133 tumors 118 were available for further clinical and radiologic evaluation Radiography was carried out in 63 patients (53%) and of these 30 (47%) were correctly diagnosed as small bowel tumors (Tables 1 2) Of the tumors 28 were benign and 90 malignant with a preponderance of carcinoid tumors leiomyomatous tumors and adenocar cinomas (Table 1)

Patients examined radiologically In no case did abdominal survey films give reason to suggest a tumor however one of the carcinoids contained calcific deposits Obstruction of the small bowel by ileus was present in 19 patients

Acute conventional follow through examinations during episodes of obstruction were carried out in 21 patients and the tumors were then diagnosed in 7 of these (33%) In 2 patients this examination was regarded as normal In the remaining 12 patients the examination indicated the presence of mechanical obstruction but no abnormalities indicating tumor were present

Small bowel examinations performed on 36 pa tients by oral administration of the barium in periods

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Table 1

The material classified according to type of tumor

Type of tumor	Radiography	No radiography	No of patients
Angiomatous lesion	3	5	8
Unspec granuloma	–	1	1
Polyp	2	–	2
Fibroma	–	2	2
Fibrolipoma	1	–	1
Lipoma	–	3	3
Peutz Jeghers disease	2	–	2
Leiomyoma	3	6	9
Leiomyosarcoma	12	7	19
Adenocarcinoma	9	9	18
Carcinoid	29	21	50
Neurofibrosarcoma	2	–	2
Malignant mesenchymal tumor	–	1	1
Total	63	55	118



Fig 1 Characteristic desmoplastic reaction with retract mesentery (→) in a patient with small carcinoid tum distal part of the ileum

with no clinical or radiographic indication of ileus disclosed 18 tumors (50%) These tumors had a mean diameter of 4 cm and the overlooked ones 2 cm but in some cases larger tumors were over looked In these cases the examinations were hampered by inadequate separation of the bowel loops or poor quality of the films Nor could the tumors be observed at a review of the films In 2 cases of large leiomyosarcomas the intraluminal part of the tumor was less than 2 cm in diameter

Six of the small bowel examinations were performed via duodenal intubation and in 5 of these the tumors were disclosed The overlooked case was a carcinoid tumor with a diameter of 3 cm without desmoplastic reaction The films were of high quality but the tumor could not be identified even at review

Angiography was performed in 32 patients Most of them had leiomyomatous tumors (9 cases) and carcinoids (15 cases) (Table 2) All leiomyomas were observed In 4 cases with carcinoids angiography did not disclose the small bowel tumor but in 3 of these cases metastases were demonstrated which led to a correct diagnosis

Patients not examined radiologically Of these 55 cases 16 were available for further clinical evaluation to find out why no radiologic examination had been performed Acute laparotomy was carried out in 7 patients due to life threatening bleeding or peritonitis Three tumors were incidentally f gynecologic operations when a palpated ab tumor was thought to be of genital origin maining 6 patients had symptoms for up years but during this period no patient ha medical care These tumors were incidental at operation (4 cases) or autopsy (2 cases)

Leiomyomatous tumors (15 cases) were both in the jejunum and in the ileum but creasing frequency in aboral direction The examination demonstrated the tumor in t case of benign leiomyoma examined and sarcomas and angiography in all 9 patie amined

Adenocarcinomas (9 cases) were found w creasing frequency in aboral direction in the je and in only one case in the ileum The small barium examination was diagnostic in the 6 (67%) in which the examination was of ad quality Angiography demonstrated the tumor 3 cases examined vessels were displaced an trated but no tumor vessels were found

Carcinoids existed only in the ileum and increasing frequency in aboral direction Mos cinoids were found in the distal part of the i Of 29 small bowel barium examinations 10 disc filling defects in the contrast medium with or out a characteristic desmoplastic reaction (Fig 1) while 11 of of 15 angiographies were nostic (73%) The desmoplastic reaction wi traction of the mesentery seen at the barium e

Table 2

Diagnostic outcome of different examinations in primary tumors of the small bowel

of tumor	Abdominal survey		Acute follow through			Barium examination		Angiography		No of patients
	Ileus	No abn	Tumor	Ileus	No abn	Tumor	No abn	Tumor	No abn	
homatous lesion							2		2	3
p		1		1						[illegible]
olipoma	1						1		1	1
z Jeghers disease		1	2				1			[illegible]
myoma	1					1	1	1		3
myosarcoma	4		1	3		5		8		12
nocarcinoma	6		2	2		4		2	1	9
noid	7	1	2	6	2	8	11	11	4	[illegible]
rofibrosarcoma		1					2	2		[illegible]
	19	4	7	12	[illegible]	18	18	24	8	63

ions was well correlated with the stellate forma of the vessels on the angiograms One patient ı small carcinoid tumors in the distal part of the m had submucosal edema and cobblestone ıation together with a marked deformity of the ım This led to the radiologic diagnosis of hn s disease (Fig 2) On operation the carcinoid ıors were found together with a marked desmo tic reaction with fibrosis in the mesentery and vel wall The tumor had spread locally to the um When the tumor was situated in the most al part of the ileum the ileo cecal valve was minent (3 cases)

wo *neurofibrosarcomas* in patients with known klinghausen s disease were included in the ıes In both the barium examinations were nor l while angiography disclosed the tumor

Two patients with known *Peutz Jeghers disease* reditary intestinal polyposis and melanin pig ntation of the skin) had multiple polyps at barium aminations

One patient had symptoms and signs of obstruc n by ileus At operation adhesions were found ether with a smooth polyp with a diameter of 1 ı The polyp had not caused the obstruction

One patient had intermittent melena and severe emia Barium examinations of the stomach small bowel and colon were considered normal as was ıgiography of the superior mesenteric artery At ploration a tumor with a diameter of 3 5 cm × 5 5 ın was found 40 cm distal to the ligament of Treitz he tumor had a small intraluminal part At micro opic examination the tumor was found to be a brolipoma

Discussion

Carcinoma of the small bowel is rare it accounts for only 3 to 6 per cent of all gastrointestinal neoplasms and less than 1 per cent of all malignant tumors (EBERT & ZUIDEMA 1965) In this region of Southern Sweden all pathologic examinations are performed at a few hospitals In spite of this fact a few tumors may have been missed and thereby the figure of a mean annual incidence of 1 33 per 100 000 inhabitants may be low

The diagnosis is difficult to make preoperatively because the condition is uncommon in clinical practice the possible existence of such a tumor thus not being taken into account and because the symptoms are vague and often unspecific (SILBERMAN et coll) Although tumors of the small bowel are rare 60 per cent of all gastrointestinal sarcomas are located in the small bowel (SKANDALAKIS et coll 1962)

In a series of 659 cases from the Mayo Clinic equal numbers of benign and malignant tumors were found leiomyomas (including leiomyosarcomas) and carcinoid tumors made up 23 per cent each adenocarcinomas 13 per cent (GOOD 1963) In the present series carcinoids preponderated (43 % of all the tumors) The number of malignant tumors was also higher than expected from other series when compared with the benign tumors

The frequency with which the small bowel tumors can be correctly diagnosed before operation or autopsy varies In a review of the literature SANDERS & AXTELL (1964) found 828 carcinoid cases and concluded that these tumors could only exceptionally be diagnosed preoperatively and that the

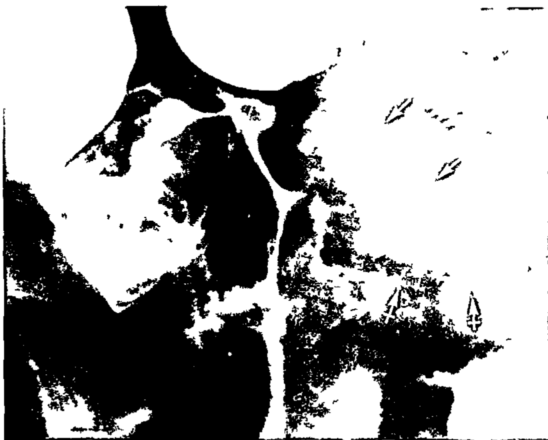


Fig 2 Infiltration of the distal part of the ileum (↔) and marked edema in proximal parts of the ileum (→) with cobblestone formation Marked edema and deformity of the cecum The lesion was initially diagnosed as Crohn s disease At operation was disclosed and a marked desmoplastic reaction was

majority was found on autopsy or incidentally at operation In other series the preoperative diagnosis varied in frequency between 21 and 63 per cent (PAGTALUNAN et coll 1964 STRAUCH 1964 OSTERMILLER et coll 1966 VUORI & VUORI)

MOERTLER et coll (1961) in their survey of 209 carcinoid tumors had only 15 preoperatively performed radiologic examinations of the small intestine of these only 6 revealed some kind of occlusive tumour In comparison with their series the present one contains a significantly higher proportion of radiologic examinations and also a higher proportion of correct preoperative diagnoses The poor results reported by MOERTLER et coll led them to conclude that radiologic examinations yield only negative or misleading results a statement that is not valid according to the result in the present series

Radiologic examinations with barium have been proved to reveal a distinct appearance of abnormalities in neoplasms of the small bowel (GOOD MARSHAK & LINDNER 1976) According to DARLING & WELCH (1959) these appearances are so character

diagnosis could be made in 84 per cent of their of small bowel tumors This is in contrast present series where only the adenocarcinomas carcinoids exhibited a characteristic appe while other types of tumors could not be differ ated with any degree of certainty

It appears that selective visceral angiogra mandatory in order to achieve a diagnostic acc of the level of DARLING & WELCH

A correct preoperative radiologic diagnosis barium contrast examinations was achieved of 66 patients reported by SILBERMAN et coll T material consisted of 32 malignant and 34 be tumors They found a higher preoperative diagn rate among malignant tumors This was ascribe the fact that these more often caused sym leading to an examination of the small bowel their benign tumors 16 were found incidentally autopsy Also in the present series a higher portion of correct preoperative diagnoses in the group with malignant tumors compared the benign group

-closed often have a considerable size (RAMER -oll 1971 KAUDE et coll 1972) The angiographic pearance of the leiomyomatous neoplasms are her constant and can be demonstrated by selec e visceral angiography (BOIJSEN & OLIN 1964 AMER et coll KAUDE et coll) The discrepancy tween barium examinations of the small intestine d angiography in leiomyomas has been pointed t by RAMER et coll who reported 4 cases with strointestinal hemorrhage The barium examina ns failed in spite of the fact that they were re ated while angiography revaled the tumors their te and localization Their poor result with barium aminations is in contrast to that of KAUDE et coll ho recognized small bowel leiomyomas in 9 of 11 ses examined with barium In all reported 13 cases giography revealed the tumors These latter ures are in accordance with those in the present ries

Carcinoid tumors are often small when diagnosed ie carcinoids have a characteristic angiographic pearance (BOIJSEN et coll 1974) In the desmo- astic tissue initiated by the carcinoid tumor cal im deposits may appear (BOIJSEN et coll BAL IAZAR 1978) but are not pathognomonic as they cur also in leiomyosarcomas (KAUDE et coll) In is series one carcinoid tumor contained calcific posits The great variety of the appearances of ircinoid tumors found at barium examinations has en pointed out by several authors (SKANDALAKIS et coll BANCKS et coll 1975 SCHLANGEN 1976) he carcinoid tumors which were diagnosed pre peratively in the present series had a strong desmo- lastic reaction

The adenocarcinomas arise from the mucosa and produce like their counterpart in the left colon a ocalized stricture Therefore unlike leiomyomas nd carcinoids they cause early obstruction while bleeding is a late sign

It is apparent that small bowel tumors are more asily detected in the jejunum Adenocarcinoma is also relatively easy to diagnose This can be due to their ability to cause obstruction in contrast to leio- myosarcomas which often have an extraluminal mode of growth However the leiomyosarcoma usually bleeds which favors early clinical detection

Angiography is the examination of choice for demonstration of the exact tumor size and it is also accurate in predicting the specific type of the tumor Angiography should be used in all patients with un explained hemorrhage from the gastrointestinal tract (SHEEDY et coll 1975) Chronic complaints of ab- dominal pain even if these are unspecific also con stitute an indication for angiography (KINKHAB WALA & BALTHAZAR 1978)

The present series indicates that the clinical and radiologic diagnosis of small bowel tumors is not as discouraging as was presumed

SUMMARY

The value of radiography in patients with tumors of the small bowel was assessed retrospectively in 63 patients who had been subjected to radiography in a series of 118 patients treated for such tumors Thirteen of 17 jejunal tumors (76%) and 19 of 46 ileal tumors (41%) were diag nosed preoperatively Elective barium examination of the small bowel was performed in 36 patients in whom the tumors were diagnosed in 18 When the small bowel examination was performed during obstruction 7 of 21 tumors were diagnosed With the barium examination adenocarcinomas and carcinoid tumors were often diag nosed correctly In 32 patients angiography was carried out and the nature of the tumor was disclosed in 24 (75%)

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CISTERNAL ABNORMALITIES PRODUCED BY CLINICAL TUMOURS IN THE POSTERIOR CRANIAL FOSSA

I Cerebellar tumours

M LINDQVIST

Vew methods for radiographic examination of the arachnoid cisterns have been introduced during last few years e g computer tomography)UNSFIELD 1973) computer cisternography .EITZ & HINDMARSH 1974 GREPE & GREITZ 7) conventional radiography of the cisterns ng water soluble contrast medium (GREPE 1975 BERSON et coll 1976) These methods have ualized the need for a systematic detailed analysis the cisternal abnormalities in different tumour ations in the posterior cranial fossa

Since the introduction of lumbar encephalography OBERTSON 1941 1957 LINDGREN 1949) the distor n of subarachnoid cisterns has been used in the agnosis of posterior fossa tumours mainly in order define extraaxial tumours and to distinguish these om intraaxial tumours (LINDGREN 1950 CASTEL ANO & RUGGIERO 1953 FALK 1953 RUGGIERO)56 LILIEQUIST 1959 b)

However for the diagnosis of intraaxial tumours isternal abnormalities have been of less importance ven after the presentation of the normal radio raphic anatomy of the cisterns (LILIEQUIST 1959 a) nd after improvement of the pneumographic tech ique by means of rotation chairs and the easy appli ation of tomography which made it possible to utline details of the subarachnoid cisterns as a natter of routine

Already in 1935 DYKE & DAVIDOFF reported ton illar herniation and compression of the cisterna pontis and the cisterna magna in cases with expand ing lesions of the posterior fossa LINDGREN & DI CHIRO (1953) described the deformity of the aque duct and the quadrigeminal cistern in patients with tumours located in the posterior fossa RUGGIERO (1957) reported on some cisternal abnormalities in a clinical material of posterior fossa tumours exam ined by means of encephalography LILIEQUIST (1963) reported briefly on cisternal abnormalities associated with tumours in the pons and cerebellum and he described for instance changes in the shape of the quadrigeminal cistern for different tumour locations NEWTON (1968) reported cisternal distor tion in several tumour locations in the posterior fossa mainly tumours growing within the cisterns or otherwise directly affecting them Some cisternal abnormalities associated with intra and paraven tricular tumours of the posterior fossa especially in the peritonsillar spaces were reported by MÖLLER (1974)

A total comprehensive and detailed description of the cisternal changes resulting from tumours in different locations has however not been given Therefore a general survey and analysis of the appearances of the cisterns in cerebellar tumours has been performed and the results are now reported with a suggestion how the distortion of the cisterns can be used for localizing the tumours

Definitions For the orientation of the structures of the posterior fossa the principles introduced by CORRALES & GREITZ (1972) have been used i e anteriorly–posteriorly perpendicular to the clivus

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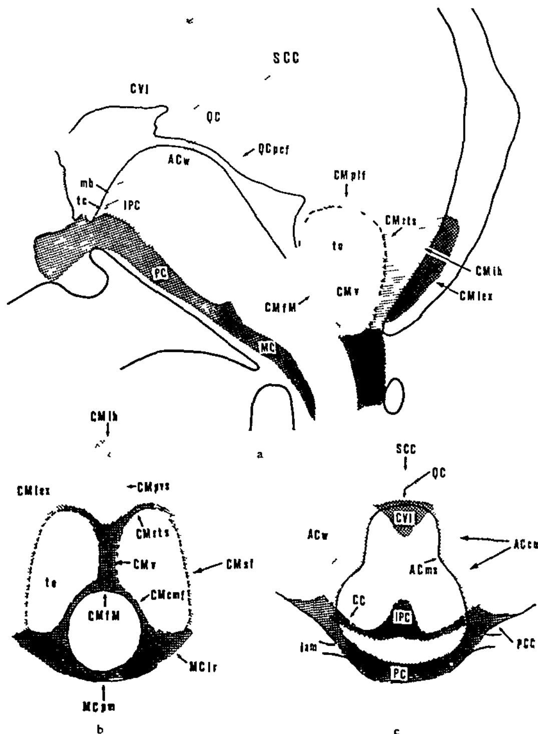
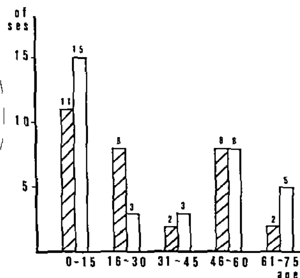


Fig 1 Drawings of the subarachnoid cisterns a) Lateral view b) Axial view of the cisterns inferior to the fourth ventricle c) Axial view of the cisterns adjacent to the tentorial notch (From LINDQVIST 1978) Labelled structures AC=ambient cistern (cm=circum-mesencephalic part ms=mesencephalic sulcus w=wing) CC=crural cistern CM=cisterna magna (cmf=cerebellomedullary fissure fM=foramen of Magendie ih=interhemispheric part lex=lateral extension plf=posterolateral fissure pvs=paravermian sulcus rts=retrotonsillar s[…] secondary fissure v=vallecula) CVI=cisterna veli […] iam=internal auditory meatus IPC=interpeduncular […] mb=mamillary body MC=medullary cistern (lr=later[…] pm=premedullary part) PC=pontine cistern PCC=p[…] bellar cistern QC=quadrigeminal cistern (pcf […] fissure) SCC=superior cerebellar cistern tc=tuber c[…] to=tonsil

superiorly and inferiorly at right angles to this perpendicular This means among other things that a beam direction parallel to the clivus is termed the axial projection Nomenclature and a schematic survey of the normal anatomy of the cisterns are presented in Fig 1 Patients aged 0 to 15 ye[…] termed children patients aged 16 years or m[…] termed adults

The ventricular sy[…] is classified as w[…] (a) *in adults* if the […] index as d f[…]



2 Sex and age distribution of 65 cases of cerebellar tumours
nales ☐ females

Table 1

Cerebellar tumours in children and adults

Type of tumour	Children (0–15 years)	Adults (16 years or more)	Total No of cases	Total Per cent
Juvenile astrocytoma	17	8	25	38 5
Hemangioblastoma (Lindau)	1	9	10	15 4
Metastasis	0	8	8	12 3
Ependymoma	3	4	7	10 8
Medulloblastoma	5	2	7	10 8
Meningioma	0	5	5	7 8
Astrocytoma poly morphous	0	2	2	3 1
Angioma	0	1	1	1 5
Total	26	39	65	

NDGREN is more than 0 33 or in cases where the ontal horn index cannot be evaluated the width the third ventricle is more than 12 mm (LINDGREN ›1 LONNUM 1966) (b) *in children* if the frontal rn index is more than 0 30 or the width of the third ntricle more than 8 mm (LODIN 1968)

Material and Methods

The material consisted of the cerebellar tumours a series of patients with posterior fossa tumours camined by encephalography at the departments of uroradiology at the hospital of Umeå and Karo nska Sjukhuset Stockholm during the period 1969 ›) 1975 Patients previously operated upon in the osterior cranial fossa were not included

The examination technique was the same at both lepartments and during the whole period The pneu nographic examination started with a lumbar en ephalography in accordance with the technique de scribed by LINDGREN (1949) and later modified by GREITZ & GREPE (1967) In cases with increased intracranial pressure a prophylactic burr hole was made and sometimes a ventricular catheter was inserted The examinations were carried out using a Mimer stand with rotation chair and tomography In addition to standard films with varying magnifi cation factors tomography of the posterior fossa with a constant magnification factor of 1 4 was carried out in the axial and lateral projection in almost all cases In the majority of cases with in sufficient passage of gas to the ventricular system supplementary ventriculography was also per formed usually on the same day

The total number of patients was 76 and of these only those cases have been included in which the type and position of the tumour was confirmed at surgery or autopsy For benign tumours a time inter val of 6 months between encephalography and operation was accepted for malignant tumours a maximum of 2 months A total of 11 cases were ex cluded 4 cases in which surgery was not performed because of old age or complicating disease 5 cases with multiple tumours multicentric tumour growth or for other reasons not definitely determined loca tion one case with too long an interval between encephalography and surgery one case in which encephalography failed completely for technical reasons

The remaining 65 cases form the basis for the present evaluation The sex and age distribution of the material appears in Fig 2 and the types of tu mours in Table 1

The size and position of the tumours were finally established by two experienced neuroradiologists who had access to all neuroradiologic examinations surgical and autopsy reports

Of the 65 cases 44 have been classified as cerebel lar tumours according to the definitions used by CORRALES & GREITZ 15 cases as paraventricular tumours according to the definitions of MÖLLER and 6 as extraaxial cerebellar tumours *Pontine angle* tumours were not included

Many of the paraventricular tumour positions are

Table 2

Cerebellar tumours divided into 8 groups according to their positions

Tumour position			No of cases
Midline tumours or tumours of the vermis	A I	(A 1 Ia)	11
	A II	(A 2 IIa A 2 ex)	5
	A III	(A 3 IIIa 1 IIIa 2 A 3 ex)	9
Total			25
Lateral tumours or tumours of the hemisphere	B I	(B 1 B 1+B 2)	7
	B II	(B 2 B 2 ex)	7
	B III	(B 3 Va 2)	12
	B IV	(B 4 VIa)	9
	C	(C C ex)	5
Total			40

by definition identical or almost so with the corresponding cerebellar positions and have therefore been grouped together The positions of the extra axial cerebellar tumours have a close relation to those of the corresponding intraaxial tumours and have therefore been treated in common

After these regroupings the following tumour positions were obtained 3 groups of midline tumours called A I A II A III roughly corresponding to tumours in the superior posterior and inferior vermis respectively 5 groups of lateral tumours termed B I B II B III B IV and C C corresponding to the lateral part and B to the medial part of the cerebellar hemispheres with positions B I adjacent to the tentorial notch B II adjacent to the inferior surface of the tentorium B III adjacent to the occipital bone and B IV adjacent to the pontine angle In Table 2 the number of cases in each position is recorded and the original positions according to CORRALES & GREITZ and MÖLLER are given in parentheses

The films were reviewed with regard to filling and distortion of different cisternal structures and also filling and size of the ventricular system Distortion of the cisterns was graded as none minimum moderate or marked The recorded changes in cisternal size and shape were related to the different tumour positions by computer analysis For technical reasons all lateral tumours in this connection were treated as if situated on the right side and in all cases of midline tumours with a tendency to lateralization the predominance was treated as if it right sided

Results and Discussion

In Tables 3 4 and 5 the frequency of fil average distortion of the most important ci structures are given for tumours in the the cerebellar hemispheres In Table 6 som ternal abnormalities for tumours with different tions in the vermis and the cerebellar hemis are summarized Only cisternal structures fil least 20 per cent of the cases and regarded formative as regards the localization of the have been included in the tables

Cisterna magna

Distortions of this cistern are s Table 3

Tonsillar herniation below the foramen m was present in the majority of cases and the tion was as a rule more marked with slowly g tumours e g juvenile astrocytomas than with r ly growing tumours such as medulloblastoma metastases The shape of the herniated t seemed to be of less importance in differen these types of lesions

With tumours of the vermis tonsillar hern was present in 90 per cent of the cases the ex tions consisted of cases of intra and extracereb tumours in position A III in which the tonsils separated by the tumour so that they could herniate through the foramen magnum

With tumours of the cerebellar hemispheres sillar herniation was present in 87 per cent of cases the exceptions consisted of a few cases tumours in position B III in which the tumour placed the cerebellum with the tonsils superior

Tonsillar herniation caused by tumours in posterior cranial fossa was described by DYK DAVIDOFF and has ever since been regarded as dicative of expanding lesion in the posterior cr fossa RUGGIERO (1957) for instance found to herniation in all of his 25 cases of cerebellar mours LILIEQUIST (1960) and WICKBOM & HA FEE (1963) pointed out that the herniation as a r was more marked in slowly growing tumours

The cervical medulla was in the majority of ca displaced anteriorly below the foramen m but in a few cases posteriorly instead (Fig 3) T reason for this posterior displacement was n

Table 3

Filling and distortion of the cisterna magna in cerebellar tumours All hemispheric tumours treated as if situated on the right side Symbols and abbreviations a=anterior p=posterior s=superior i=inferior R=right L=left 0=no change (+)=minimal change or increase +=moderate change or increase ++=marked change or increase (−)=minimal decrease −=moderate decrease −−=marked decrease open space=structure not possible to evaluate

Tumour position	Cerebellum			
	Vermis		Hemisphere	
	Filling (%)	Distortion	Filling (%)	Distortion
Cisterna magna				
1 Extracranial part lat proj	100		100	
tonsillar herniation		++		++
a p displacement of cervical medulla		a(+)		a(+)
2 Interhemispheric part lat proj	92		97	
s i diameter		−−		−
3 Foramen of Magendie lat proj	40		20	
a p displacement		a++		a+
4 Vallecula axial proj	52		70	
width		(−)		−
lateral displacement		0		L++
5 Retrotonsillar spaces lat proj	12		12	
a p displacement				
s i displacement				
6 Cerebellomedullary fissures				
a right side axial proj	24		17	
a p displacement		0		a++
lateral displacement		R(+)		L++
b left side axial proj	24		20	
a p displacement		0		0
lateral displacement		L(+)		L++
7 Paravermian sulci axial proj	24		24	
width of inferior vermis		++		0
lateral displacement of inferior vermis		0		L++

ıdent—it may as was pointed out by JIROUT 959) be the consequence of a downward hernia on of the brain stem in the foramen magnum

The interhemispheric part of the cisterna magna as in the lateral projection usually compressed gainst the occipital crest However in a few cases f tumour in position B III the cistern was widened Fig 4) due to an upward displacement of the inerior vermis by a very large tumour

The compression of the cisterna magna against he occipital crest in the case of cerebellar tumours vas pointed out by DYKE & DAVIDOFF and KRAU sOVA & JIROUT (1963) but the paradoxic widening n some B III tumours has not been described previously

The foramen of Magendie was displaced anteriorly in all tumours of the vermis With tumours in the cerebellar hemispheres the foramen of Magendie was seldom identified When visible it was markedly displaced anteriorly with tumours in the B II position and slightly so in the B I and B III positions and usually not displaced at all in the B IV and C positions (Table 6)

The vallecula could not be identified in the axial projection in more than half of the cases Axial views with slightly varying beam direction and axial tomography were often necessary for definite identification of the vallecula and for distinguishing it from superimposition of the interpeduncular cistern or the anterior part of the interhemispheric fissure Poor filling of the vallecula was most common in cases with tumours in the posterior and inferior



Fig 3



Fig 4a

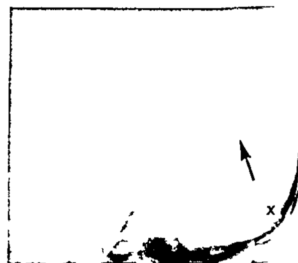


Fig 4b

Fig 3 Large tumour in the B IV position Posterior displacement of the cervical medulla (→) below the foramen magnum

Fig 4 Large tumour in the B III position with marked superior displacement of the inferior vermis (→) a) Axial projection b) Lateral projection Marked lateral displacement of the inferior vermis (→) (X=soft tissue tumour of unknown origin not explained by the examination or in the surgical report)

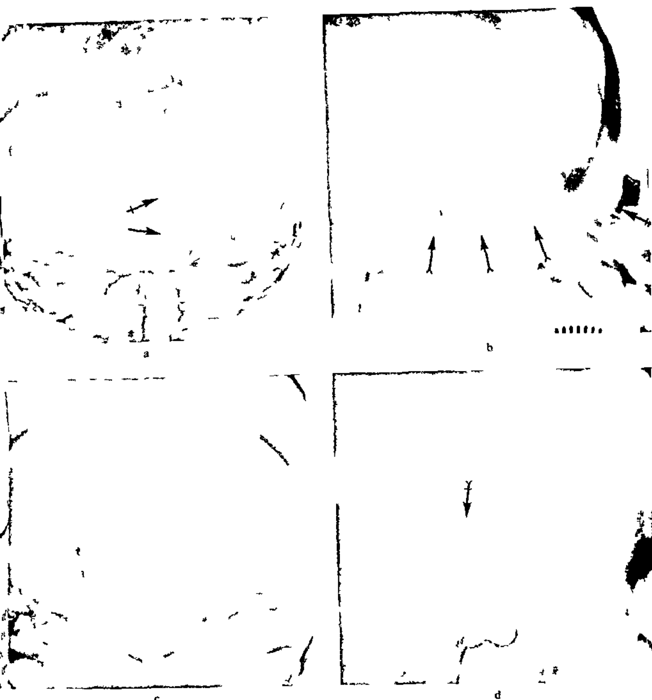
parts of the vermis (positions A II and A III) Widening of the vallecula was unusual and was only observed in some of the cases with a tumour in the inferior vermis (position A III) and in a few cases of paraventricular tumours in position B III with infiltration of the brain stem In all other cases the width of the vallecula was reduced or normal

A definite lateral displacement of the vallecula towards the contralateral side regularly occurred in hemispheric tumours (Fig 5) In tumours of the vermis situated in the midline the vallecula was not laterally displaced On the other hand with asymmetric tumours of the vermis some lateral displacement of the vallecula was observed but in such cases the degree of displacement was as a rule less than in cases of hemispheric tumours

Both RUGGIERO (1957) and LILIEQUIST (1963) have pointed out that lateral displacement of the vallecula is an important indication of lateral tumour in the posterior fossa However in RUGGIERO s series of 25 cases the vallecula could identified in the axial projection in only 2 ca[ses] MÖLLER has reported widening of the vallecu[la] cases of intra and paraventricular tumours [in the] inferior part of the posterior fossa

The cerebellomedullary fissures were often se[pa]rated in cases of tumours of the vermis espe[cially] tumours of the inferior vermis In hem[ispheric] tumours the cerebellomedullary fissure on [b]sides was displaced towards the contralateral [side] on the tumour side also in the anterior directi[on]

The paravermian sulci indicate the width of [the] inferior vermis A definite widening of the [...] vermis was present in most cases of vermis tu[mours] without any definite difference between tumours [of] the superior and the inferior vermis In hem[ispheric]



ıg 5 Tumour of the rıght cerebellar hemısphere posıtıon B II a b) Encephalography Compression and lateral displacement to the left of the vallecula (→) and the ınterhemıspherıc part of the cısterna magna (↛) Tonsıllar hernıatıon (⇸) and marked compression of the pontıne and medullary cısterns (↔) c d) Ventrıculography No fillıng of the fourth ventrıcle Only the supratentorıal part of the aqueduct ıs outlıned by gas (↮)

tumours the vermıs was slıghtly wıdened wıth tumours ın the posıtıons B I and B II In the remaınıng posıtıons the wıdth of the vermıs was normal or reduced In many cases of hemıspherıc tumours also a definıte lateral dısplacement of the vermıs was encountered (Fıg 4 a)

Wıdenıng of the ınferıor vermıs ın cases of ıntra and paraventrıcular tumours of the fourth ventrıcle was descrıbed by MÖLLER

The retrotonsıllar spaces posterolateral fissures and secondary fissures were so poorly filled ın most cases of cerebellar tumours that they could not be analysed ın detaıl

The lateral extensıon of the ıntracranıal part of

Table 4

Filling and distortion of the medullary cistern pontine cistern and the pontocerebellar cisterns in cerebellar tumours Tumour position symbols and abbreviations as in Table 3 Additional abbreviations Ra=right side rotated anteriorly Rp=right side rotated posteriorly

Tumour position	Cerebellum			
	Vermis		Hemisphere	
	Filling (%)	Distortion	Filling (%)	Distortion
Medullary cistern				
1 Premedullary part lat proj	56		42	
a p diameter		– –		– –
2 Lateral recesses				
a right side axial proj	46		55	
a p diameter		–		– –
lateral extension		–		0
b left side axial proj	46		52	
a p diameter		–		–
lateral extension		–		– –
3 Diameter of medulla oblongata				
a p diameter lat proj		–		–
transverse diam axial proj		+		+
4 Lateral displacement of medulla oblongata axial proj		0		L +
5 Rotation of medulla oblongata around axis parallel to clivus		0		Ra +
Pontine cistern lat proj	80		87	
a p diameter		– –		– –
tendency of superior part of pons to recede from clivus		0		(+)
Pontocerebellar cisterns				
1 Right side axial proj	33		31	
width of lateral part		–		– –
width of medial part		–		– –
2 Left side axial proj	58		59	
width of lateral part		–		–
width of medial part		–		–

the cisterna magna was defined in the axial projection on one or both sides in 15 per cent of the cases If unilateral filling sometimes occurred on the tumour side sometimes on the contralateral side These structures therefore have no value for the localization as was also pointed out by RUGGIERO (1957)

Medullary cistern

Distortions of this cistern are summarized in Table 4

Compression of the premedullary part of the medullary cistern was a very constant feature [of] all tumour positions In most cases of tumours of [the] vermis the medulla oblongata in the axial projec tion was moderately widened without lateral dis placement or rotation In the case of hemispheric tumours a slight widening of the medulla oblongata occurred in some cases of B I and B II tumours [and] also in paraventricular B III tumours with infiltra[tion] of the medulla oblongata In practically all cases [of] hemispheric tumours in which the medullary ci[stern] could be evaluated in the axial projection a lateral displacement of the medulla oblongata was evid[ent] Anterior rotation of the medulla oblongata on



Fig 6

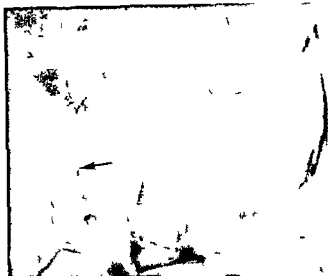


Fig 7a



Fig 7b

6 Tumour of the right cerebellar hemisphere position B II ...al tomography through the vallecula and medulla oblongata ...teral displacement of the vallecula (→) reduced a p diameter the right lateral recess (↠) and of the premedullary part (↠) the medullary cistern Medulla oblongata displaced to the left d rotated anteriorly on the tumour side

g 7 a) Tumour of the inferior vermis position A III Superior t (→) of posterior part of superior surface of the pons b) Hemispheric tumour position B III The superior part of the pons cedes from the clivus (↠)

...imour side occurred in most cases of tumour in the ...I and B II position (Fig 6) but not with other tu...nour positions (Table 6)

Compression of the medullary cistern is an impor...ant indication of an expanding lesion in the posterior ...ossa and has been pointed out by RUGGIERO (1957) ...KRAUSOVÁ & JIROUT and LILIEQUIST (1963) but ...the other distortions of the medullary cistern in ...cerebellar tumours have not been reported in detail previously

Pontine cistern

Distortions of this cistern are summarized in Table 4

Compression of the pontine cistern against the clivus was a constant finding for all tumour positions The superior and the inferior part were compressed to the same degree in all cases of midline tumours and in most cases of hemispheric tumours

A tendency of the superior part of the pons to recede from the clivus occurred in some cases of hemispheric tumours (Fig 7b) but not in vermis tumours

Also compression of the pontine cistern is a well known sign of an expanding lesion in the posterior fossa (DYKE & DAVIDOFF RUGGIERO 1957 KRAUSOVÁ & JIROUT LILIEQUIST 1963)

Pontocerebellar cisterns

Distortions of these cisterns are summarized in Table 4

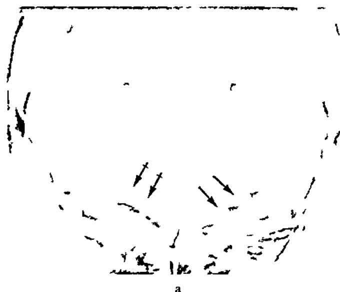




Fig 8 a) Paraventricular tumour on the left side position B III Marked compression (→) of the ipsilateral pontocerebellar cistern The contralateral cistern (↔) is not distorted b) Tentorial meningioma on the left side position C Widening (⇸) of the lateral part of the pontocerebellar cistern on the [illegible] side Marked compression of the medial part of the cist[illegible] and of the whole contralateral pontocerebellar cistern [illegible]

The pontocerebellar cistern was filled almost *twice as often on the contralateral side as on the* tumour side both in cases of hemispheric tumours and in cases of asymmetric tumours of the vermis When they were filled bilaterally the cistern on the tumour side was usually more compressed than on the contralateral side and the compression was in most cases the same in the lateral as in the medial part of the cistern (Fig 8a) Widening of the lateral part of the pontocerebellar cistern with compression of the medial part occurred in one case of extra axial meningioma in the C position (Fig 8b)

Poor filling or marked compression of the ponto cerebellar cistern on the tumour side has previously been reported by LILIEQUIST (1963) and PRIBRAM (1966) RUGGIERO (1957) found that the pontocerebellar cisterns were often compressed or poorly filled in cases with cerebellar tumours and that in cases with unilateral filling it was sometimes filled only on the side of the tumour sometimes only on the contralateral side On the other hand KRAUSOVÁ & JIROUT claimed that the pontocerebellar cistern was usually wider on the tumour side than on the contralateral side but they did not clearly distinguish between intra and extraaxial tumours

Interpeduncular cistern

Distortions of this cistern are summarized in Table 5

The inferior limit of the interpeduncular cistern is made up of the superior surface of the pons *the position of the pons can be used as a me[illegible]* of the degree of upward displacement in the [illegible]torial notch This displacement which depen[illegible] the size and position of the expanding lesion [illegible] posterior fossa can be counteracted by a wide[illegible] of the supratentorial part of the ventricular s[illegible] even to such an extent that an expected up[illegible] displacement is paradoxically replaced by a d[illegible]ward displacement (Fig 9)

The degree of supero inferior compression of interpeduncular cistern depends not only on upward displacement of the pons but to the [illegible] extent on the width of the third ventricle In c[illegible] with widening of the anterior part of the third [illegible]tricle the tuber cinereum may cause a marked c[illegible]pression of the interpenduncular cistern (Fig [illegible] In some cases especially in children this com[illegible]sion was sometimes total or nearly total and t[illegible] cistern then often took on a rabbit s ears a[illegible]ance (Fig 11) the filling defect between the t[illegible] parts probably comprising the oculomotor nerves

The degree of supero inferior compression of [illegible] interpeduncular cistern was approximately the s[illegible] for both hemispheric and vermis tumours The [illegible] diameter of the cistern was reduced in most [illegible] mours as a rule more in medial than in lateral [illegible]mours With medial tumours the a p compressi[illegible] was more marked in tumours in the superior ve[illegible] (A I) than in the inferior vermis (A III Table 6) [illegible]

Table 5

Filling and distortion of the interpeduncular cistern ambient cistern and quadrigeminal cistern in cerebellar tumours Tumour position symbols and abbreviations as in Tables 3 and 4 Additional abbreviations fr=frontally sag=sagittally i a =inferior end rotated anteriorly i p =inferior end rotated posteriorly

Tumour position	Cerebellum			
	Vermis		*Hemisphere*	
	Filling (%)	Distortion	Filling (%)	Distortion
Interpeduncular cistern				
Lat proj	80		95	
a p diameter		–		(–)
s i diameter		–		–
s i displacement of pons		s +		s +
s i inclination of the posterior part of the superior surface of the pons		s +		s(+)
Ambient cistern				
Circum mesencephalic part axial proj				
a width of posterior part				
right side	42	0	57	0
left side	50	0	47	0
b width of anterior infratentorial part				
right side	12		12	
left side	21		15	
c width of anterior supratentorial part				
right side	29	0	42	0
left side	33	0	41	0
d rotation around sagittal axis perpendicular to clivus				
right side		fr(+)		fr(+)
left side		fr(+)		sag(+)
Quadrigeminal cistern				
1 Body of cistern lat proj	72		8?	
a p displacement		0		0
kinking of quadrigeminal plate		++		++
rotation of inferior end of quadrigeminal plate		ia +		ia +
2 Precentral fissure lat proj	44		49	
a p displacement		a +		a +

...teral tumours the a p compression was moderate ...i positions B I and B II slight in the C position and ...bsent in positions B III and B IV (Table 6)

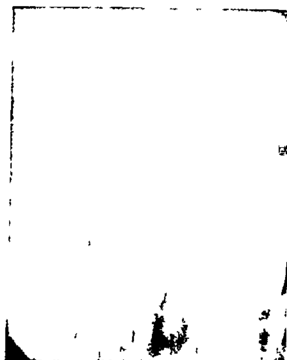
Upward displacement of the pons was observed ...oth in the case of hemispheric and vermian tu...mours but the degree of displacement varied greatly ...and was not obviously correlated with the tumour ...position

The superior tilt of the posterior part of the supe...rior surface of the pons was as a rule more evident with vermian (Fig 7a) than with hemispheric tumours

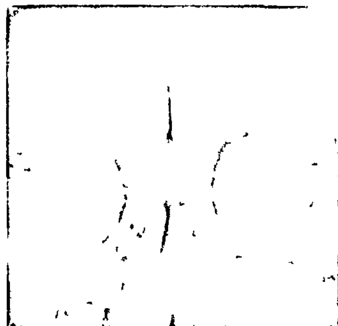
A widening of the third ventricle as the cause of compression of the interpeduncular cistern was reported at autopsy by SPATZ & STROESCU (1934) and was demonstrated radiographically by EPSTEIN (1951) RUGGIERO (1957) found an upward displacement of the pons in most cases of cerebellar tumours and in many cases also a compression of the interpeduncular cistern However he did not dis



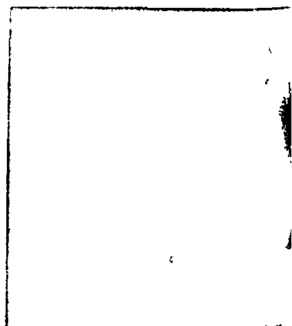
a



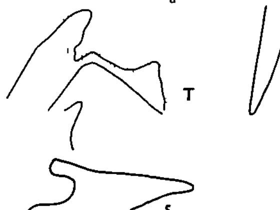
b



c



d



e

Fig 9 Astrocytoma of the inferior vermis position A III a b) First examination Lateral ventricles of ordinary size c d) Second examination 9 months later Ventricular dilatation In spite of increasing size of the tumour slight inferior herniation in the tentorial notch of both the pons and the third ventricle e) Combined drawing of b) (dotted lines) and d) (continuous lines) T = tumour

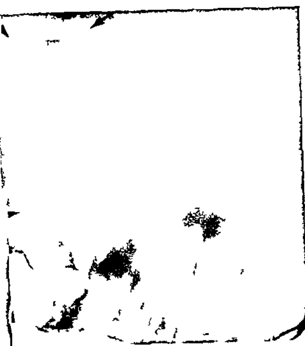


Fig 10a



Fig 10b



Fig 11

Fig 10 Tumour of the left cerebellar hemisphere position B III a) Encephalography in the sitting position lateral view b) Ventriculography in supine position lateral view The interpeduncular cistern compressed by the dilated third ventricle (→) In the sitting position the cistern of the lamina terminalis (↠) and the pericallosal cistern (⇻) are also filled

Fig 11 Lateral view sitting position 3-year-old patient with a huge tumour in the right cerebellar hemisphere position B III The interpeduncular cistern almost totally compressed and resembling a pair of rabbit s ears because of a filling defect probably caused by the oculomotor nerves (→)

ıss the significance of the widening of the third ntricle RUGGIERO & CASTELLANO (1953) de ribed a measuring method for determining an upard displacement of the posterior part of the third entricle in cases with tumours of the posterior ɔssa However also with this method the results were influenced by the width of the anterior part of the third ventricle

Ambient cistern

Distortions of this cistern are summarized in Table 5

The circum mesencephalic parts were seldom filled infratentorially especially on the tumour side The supratentorial parts were filled approximately equally often on both sides but as a rule without appreciable changes in width In vermis tumours sometimes a tendency to frontal rotation of the ambient cistern on both sides was noted while in hemispheric tumours a frontal rotation on the tumour side and a sagittal rotation on the contralateral side were sometimes observed (Fig 12 regarding this complex rotation cf also LINDQVIST 1978) However cases also existed with sym

Table 6

Cisternal abnormalities that can be used to distinguish between cerebellar tumours of different locations Symbols and abbreviations as in Tables 3 to 5

	Tumour position		
	AI	AII	AIII
Tumours of the vermis			
Cisterna magna			
Extracranial part lateral projection tonsillar herniation	++	++	+
Interpeduncular cistern lateral projection a p diameter	--	-	(-)

	Tumour position				
	BI	BII	BIII	BIV	C
Tumours of the hemispheres					
Cisterna magna					
1 Interhemispheric part lateral projection	--	-	(-)	-	--
2 Foramen of Magendie lateral projection a p displacement	a+	a++	a+	0	0
Medullary cistern axial projection a p rotation of the medulla oblongata on the tumour side	a+	a(+)	0	0	0
Interpeduncular cistern lateral projection a p diameter	-	-	0	0	(-)

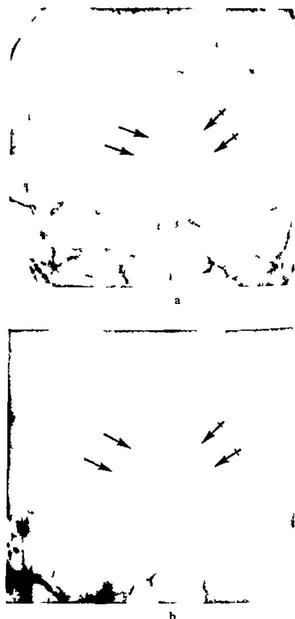


Fig 17 Metastasis in the right cerebellar hemisphere pos... Axial view a) without and b) with tomography Tenden... frontal rotation (→) of the circum mesencephalic part of ambient cistern on the tumour side and to sagittal rota... *on the contralateral side*

metric ambient cisterns in spite of lateral tumour positions

RUGGIERO (1957) stated that unilateral filling of the circum mesencephalic part of the ambient cistern was of no use for localizing posterior fossa tumours LILIEQUIST (1963) reported that the infratentorial part of the cistern on the tumour side was usually more compressed often not filled at all but that this change was subtle and not reliable for purposes of localization

Quadrigeminal cistern

Distortions of this cistern are summarized in Table 5

Displacement of the quadrigeminal cistern and the quadrigeminal plate was seldom observed appreciable distortions appeared instead as a kink in the quadrigeminal plate often combined with a rota... anteriorly or posteriorly of the inferior part of the quadrigeminal plate The width of the fourth ventricle and the aqueduct greatly influenced the appearance of the quadrigeminal cistern Cases with approximately the same tumour positions could exhibit quite different deformities of the quadrigeminal cistern depending on whether the fourth ventricle and aqueduct were widened or compressed (Fig 13) Widening of the fourth ventricle and aqueduct is present in most cases of intraventricular tumours in the fourth ventricle due to obstruction of



a



b

13 Two cases of tumour of the inferior vermis a) Fourth tricle and aqueduct compressed Abrupt reduction of the th of the aqueduct (→) where it passes through the tentorial h The inferior part of the aqueduct and the quadrigeminal plate are rotated anteriorly b) Widening of the fourth ventricle and the aqueduct The inferior end of the quadrigeminal plate is somewhat rotated posteriorly

ebrospinal fluid flow from the ventricle caused by tumour

A similar widening of the aqueduct and the fourth itricle also occurred in several cases of paraven ular tumours in the inferior part of the posterior sa mainly in the A III position but also in some ses with positions B III and B IV (Fig 14 c d) ie deformity of the quadrigeminal cistern in these ses was similar to that usually caused by tumours the fourth ventricle i e the quadrigeminal plate as more or less kinked and its inferior part was omewhat rotated posteriorly if rotated at all The ecentral fissure was in these cases usually dis aced superiorly but not anteriorly

With all other cerebellar tumour positions both the queduct and the fourth ventricle were compressed ometimes with an abrupt reduction of the width f the aqueduct at the tentorial notch (Fig 14 b) These cases also exhibited the well known and char cteristic kinking of the quadrigeminal plate with anterior and superior displacement of the precentral issure (Fig 14 a) The displacement of the lateral arts of the precentral fissure was sometimes greater han the displacement of the aqueduct

The kinking of the quadrigeminal plate was well correlated to the presence of ventricular dilata tion In 28 cases with ventricular dilatation in which the quadrigeminal cistern could be evaluated the quadrigeminal plate was definitely kinked in 22 cases slightly in 4 cases and without kinking in 2 cases Of the 4 cases without ventricular dilatation in which the quadrigeminal cistern could be evaluated no kinking of the quadrigeminal plate occurred in 3 cases and slight kinking in one case

The deformity of the aqueduct and the quadri geminal cistern was reported in detail by LINDGREN & DI CHIRO for different types of posterior fossa tumours as also the posterior rotation of the inferior part of the quadrigeminal plate in cases with a widening of the aqueduct and the fourth ventricle for instance in cases with tumours of the inferior vermis LILIEQUIST (1963) and PRIBRAM also de scribed this appearance of the quadrigeminal cistern in cases of tumours in the inferior vermis and in the fourth ventricle

Remaining cisterns

The crural cisterns were filled on one or both sides in 40 per cent of the cases approximately as often on the side of the tumour as on the contralateral side and the appearance of these cisterns did not seem to be correlated with the tumour positions

The chiasmatic cistern was filled in approximately 90 per cent of the cases It was moderately com pressed by the anterior part of the third ventricle in most cases of ventricular dilatation but was other wise without specific distortion

The cistern of the lamina terminalis was filled in 15 per cent of the cases also without diagnostic appearance

The superior cerebellar cistern was identified in the lateral view in 40 per cent of the cases It was

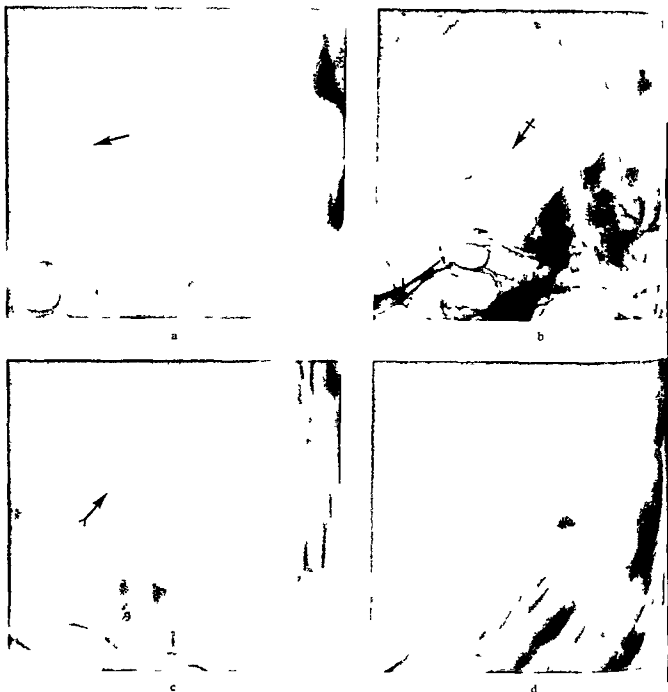
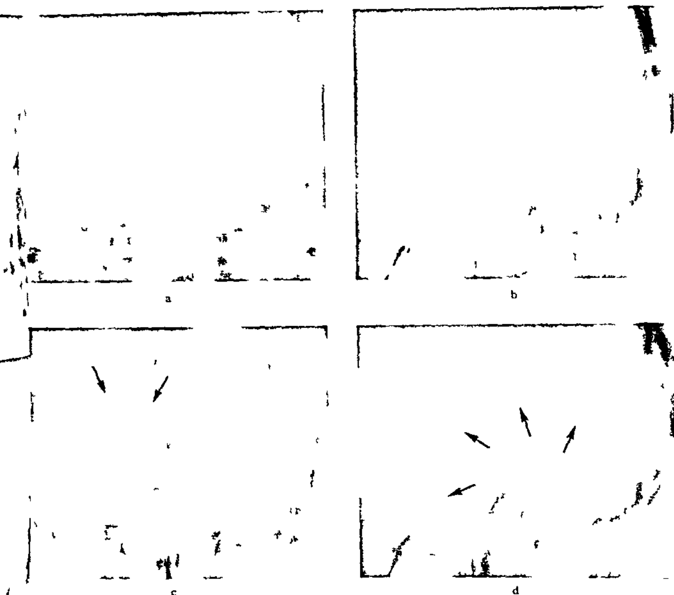


Fig 14 a) Encephalography and b) ventriculography of a tumour in the BIV position Compression of the fourth ventricle typical kink and anterior displacement of the inferior part of the quadrigeminal plate (→) and the aqueduct (→) c) Encephalography and d) ventriculography of another tumour in the BIV po... Dilatation of the fourth ventricle Inferior part of the q... geminal plate is not rotated anteriorly (→) because of wide... the fourth ventricle and the aqueduct

often difficult to distinguish from superimposed supratentorial structures such as the calcarine and the posterior parietal fissures The shape of the superior vermis could be evaluated in 20 cases 17 of which exhibited a bulging of the superior vermis as in tumours of the posterior compartment in 3 cases the appearance of the superior vermis was normal

In the axial view the superior cerebellar cistern could be evaluated in approximately 20 per ce... d the cases With lateral tumours it was somew... more often filled on the contralateral side tha... the tumour side In a few cases extraaxial tu... were surrounded by gas in the superior cereb... cistern (Fig 15)

Bulging of the superior cerebellar cistern w... described by RUGGIERO (1957) in 4 of 25 cases of cerebellar tumours



ig 15 Tentorial meningioma on the right side a b) Tomo-aphy before air filling of the cisterns The aqueduct and the urth ventricle are deformed as with large tumour of the pontine angle c d) Tomography after air filling of the cisterns The tumour (→) almost completely surrounded by air

The pericallosal cisterns were filled on one or oth sides in 40 per cent of the cases In the axial rojection *the wings of the ambient cisterns* were bserved in approximately 50 per cent of the cases and *the cisterna veli interpositi* in approximately 0 per cent of the cases All these cisternal structures were often markedly dilated in cases with ventricular dilatation but of normal size or only slightly dilated in cases without hydrocephalus Unilateral filling did not correlate with the tumour side In no case was any rotation or lateral displacement of the cisterna veli interpositi observed

Widening of the pericallosal cisterns the cisterna veli interpositi and the wings of the ambient cistern are well known indirect signs of expanding lesions of the posterior fossa described by SASSAROLI (1955) and by SCHECHTER et coll (1958) PRIBRAM pointed out that unilateral abnormalities are not correlated to the side of the tumour and he also reported that the same cisternal appearances could be present in cases of ventricular dilatation from other causes than expanding lesions of the posterior fossa ROTH et coll (1972) claimed that the mechanism behind these cisternal distortions is to be found in mechanical changes of the cerebrospinal fluid circulation

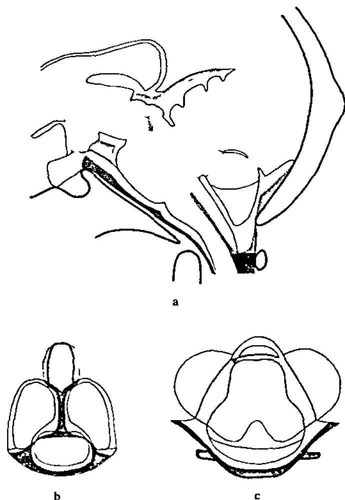


Fig 16 Drawings of some important cisternal deformities in tumours of the vermis a) Lateral view b) Axial view of the cisterns inferior to the fourth ventricle c) Axial view of the cisterns adjacent to the tentorial notch The normal appearance of the cisterns is indicated by continuous lines cisternal structures possible to evaluate in tumour cases by shaded areas (cf Fig 1)

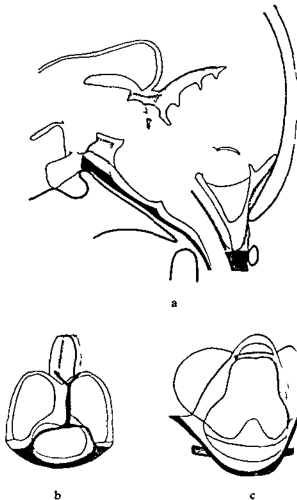


Fig 17 Drawings of some important cisternal deform tumours of the right cerebellar hemisphere a) Lateral vie Axial view of the cisterns inferior to the fourth ventricle c) view of the cisterns adjacent to the tentorial notch (cf Fig

Comparison with cisternal distortions caused by experimental tumours

Total agreement does not exist between the cisternal abnormalities in clinical cases and those produced by experimental tumours (LINDQVIST) and is not to be expected Cisternal distortions caused by ventricular dilatation and not by the tumour itself could not be imitated experimentally for instance widening of the pericallosal cisterns the ambient wings and the cisterna veli interpositi compression of the chiasmatic cistern and interpenduncular cistern One of the most striking differences was that the evident contralateral displacement and rotation of the cisterna veli interpositi present in almost all cases of lateral experimental tumours was not observed at all in the clinical material This might be due to the fact that in the experimental series there was no supratentorial intracranial pressure A la displacement of the brain stem inferiorly thus r sulted in a passive displacement of the supra rial part of the brain stem towards the contrala side and thereby also a displacement of the cis veli interpositi Other differences are easily e plained by the fact that the experimental ball tumour developed instantaneously without the sl remodelling of the surrounding brain structures th occurs in clinical cases

However in many respects a good agreement found between the clinical and the experim situation This is true of many of the abnorma of the cisterna magna the medullary cistern and pontine cistern For instance the changes in t shape and position of the medulla oblongata are great importance for determining the tumour po

Typical cisternal distortions caused by tumours in the vermis and in the cerebellar hemispheres

Lateral projection

he abnormalities are similar for tumours in the ver is and in the hemispheres In most cases the fol wing cisternal distortions are present

umour of the vermis	Tumour of the hemispheres
onsillar herniation Exception Intra and extra axial tumour in the inferior part of the posterior fossa with marked separation of the tonsils	Tonsillar herniation Exception some cases of tumour in the inferior part of the posterior fossa with marked superior displacement of the cerebellum
ompression of the inter emispheric part of the isterna magna against the ccipital crest	Compression of the inter hemispheric part of the cisterna magna against the occipital crest Exception Some cases of tumour in the inferior part of the posterior fossa with marked superior displacement of the cerebellum
nterior displacement of the Magendie	Anterior displacement of the foramen of Magendie Exception Lateral hemispheric tumour and tumour close to the pontine angle
ompression of the pre medullary part of the medullary cistern	Compression of the pre medullary part of the medullary cistern
Compression of the pontine cistern	Compression of the pontine cistern
Moderate superior–inferior compression of the inter peduncular cistern especially in cases with hydrocephalus Moderate a p compression of the cistern	Moderate superior–inferior compression of the inter peduncular cistern especially in cases with hydrocephalus
Kinking of the quadrigeminal plate	Kinking of the quadrigeminal plate
Anterior rotation of the inferior part of the quad rigeminal plate Exception Tumour with widening of the fourth ventricle	Anterior rotation of the inferior part of the quad rigeminal plate Exception Tumour with widening of the fourth ventricle
Compression of the superior cerebellar cistern with bulging of the superior vermis	Compression of the superior cerebellar cistern with bulging of the superior vermis

Axial projection

Important differences exist between the abnormalities resulting from tumours of the vermis and those resulting from hemispheric tumours In most cases the following cisternal distortions are present

Tumour of the vermis	Tumour of the hemispheres
Widening of the inferior vermis	Compression and contra lateral displacement of the inferior vermis
Slight compression and no lateral displacement of the vallecula Exception Tumour in the inferior part of the posterior fossa may cause a widening of the vallecula In asym metric tumour some lateral displacement of the vallecula may occur	Compression and contra lateral displacement of the vallecula
Anterior compression and some widening of the medulla oblongata Symmetric com pression of the lateral recesses of the medullary cistern Exception Some asym metry may occur in cases of asymmetric tumour	Contralateral displacement of the medulla oblongata with compression of the lateral recess of the medullary cistern on the contralateral side In cases with tumour of the posterior part of the hemisphere sometimes an anterior rotation of the medulla oblongata occurs on the tumour side
Symmetric and uniform compression of the ponto-cerebellar cisterns Exception Some asym metry may occur in cases of asymmetric tumour	Asymmetric compression of the pontocerebellar cisterns with more marked compres sion on the tumour side than on the contralateral side The cisterns are usually com pressed to the same extent in their medial and lateral parts Exception Extraaxial tumour may cause a widen ing of the pontocerebellar cistern on the tumour side
Slight symmetric rotation frontally of the circum mesencephalic part of the ambient cistern	Slight frontal rotation of the circum-mesencephalic part of the ambient cistern on the tumour side and slight sagittal rotation on the con tralateral side

tions The complex rotation movements of the circum mesencephalic parts of the ambient cistern were also to some extent present in the clinical material

Typical cisternal abnormalities in cerebellar tumours of the vermis and the right hemisphere respectively are listed on page 103 and illustrated in Figs 16 and 17

The cisternal abnormalities associated with other tumour locations in the posterior fossa will be reported separately with a discussion of the possibilities of differential diagnosis

SUMMARY

A detailed analysis of the deformities of the subarachnoid cisterns was carried out in a clinical material of 65 cases with cerebellar tumours examined by encephalography The distortion of the cisterns was related to 8 different tumour positions and the results compared with those from a previous experimental investigation Typical cisternal distortions for cerebellar tumours are listed constituting a basis for a general analysis of the cisternal abnormalities demonstrated by whatever means of neuroradiologic procedure employed pneumography computer tomography or cisternography with positive contrast medium

ACKNOWLEDGEMENTS

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RADIOGRAPHIC HEALING AND REMODELLING OF CORTICAL AND CANCELLOUS BONE GRAFTS AFTER RIGID PLATE FIXATION

Experiments in the rabbit

P WARIS E KARAHARJU P SLATIS and P PAAVOLAINEN

The healing of bone grafts after plate osteosynthe s has not been widely investigated radiographic ly OLERUD & DANCKWARDT LILLIESTRÖM (1971) nd HUTZSCHENREUTER (1972) showed that cortical terposition grafts mend by primary bone healing ithout evident periosteal reaction

The osteoinductive capacity of cancellous bone ceeds that of cortical bone (ABBOT et coll 1947 CHWEIBERER 1971) Ever since NICOLI (1956) pre nted his method of cancellous interposition graft ig it has been widely used in connection with plate steosynthesis The cancellous graft provokes abun ant bone formation (SIFFERT 1955) in connection vith rigid osteosynthesis cancellous interposition grafts also seem to mend by primary bone healing DÜKER et coll 1975)

The incorporation of a bone graft is accomplished y so-called creeping substitution (STRINGA & MIGNANI 1967 ALBREKTSSON 1971 ENNEKING et coll 1975) which is characterized by the simulta neous resorption of necrotic old bone and the forma tion of new bone on the lattice work of old bone trabeculae This repair is vivid and usually complete in cancellous grafts (BOYNE 1970 SIFFERT 1955) but in cortical grafts it is retracted for years and can remain incomplete (ALBREKTSSON ENNEKING et coll)

No comparison of cortical and cancellous inter position grafts after rigid plate fixation appears to have been made Therefore using radiography the healing of cortical and of cancellous grafts were compared concomitant changes in the plated host bone analysed and the remodelling of the grafts followed for one year

Material and Methods

Operative technique The material consisted of 130 rabbits weighing from 2450 to 5100 g The animals were anaesthesized with mebumal natri um and ether The right tibiofibular bone was ex posed through a straight incision A 6 mm long seg ment of the tibia was cut with a double blade cir cular saw during continuous cooling with saline the proximal osteotomy was performed just below the tibiofibular junction

In 70 of the rabbits the cortical bone transplant was turned 180 and replaced in the defect (A in Fig 1) In the other 60 rabbits the defect was filled with a 6 mm long cancellous graft from the anterior iliac crest (B in Fig 1) Osteosynthesis was made with a 6-hole DCP/ASIF plate attached to the bone with 5 screws in the cortical graft series and 6 in the cancellous graft series All the screws were tightened with a calibrated torque wrench which exerted an axial force of 5 to 10 kPa In the cancel lous graft this procedure resulted in a moderate squeezing of the trabeculae and loss of axial com pression force in the cortical graft compression was exerted on the tubular graft

After the operation the animals wore no external splints and were allowed to move freely in separate

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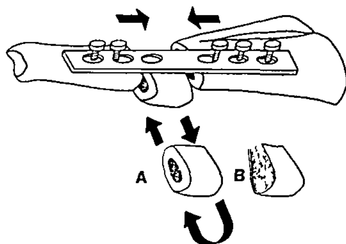


Fig 1 Operative technique A—Cortical transplant turned 180 and replaced B—Defect filled with cancellous graft



Fig 2 Diagram of the cortical bone transplant 12 weeks after rigid plate fixation (cf Fig 3c) Sites at which the radiographic abnormalities were semi-quantitatively recorded a) New bone formation around the screw b) new bone formation around the plate c) periosteal reaction opposite the plate d) resorption in cortical host bone under the plate e) incorporation of the graft f) resorption of the graft

cages Animals were killed 1 3 6 12 24 36 and 52 weeks after the operation the tibiofibular bones *removed and the soft tissues stripped off leaving* the periosteum and all callus tissue intact

In the cortical bone graft series 20 of the 70 rabbits were excluded because of fracture or loosening of the implant for another 10 no films were obtained because of technical errors In the cancellous graft series 5 of the 60 rabbits were excluded because of fracture and no films were obtained in 10 Thus for further analysis 40 animals with cortical grafts and 45 animals with cancellous grafts remained

Radiography of the plated bone was performed immediately after the operation and before and after the removal of the plate after the animal had been killed *Agfa-Gevaert Structurix D7 mammography* film was used and exposed with a Machlett 80- tube at 70 kV 10 mA for 3 5 s at a focus-object distance of 1 m

Transverse specimens of the proximal and host bone of the graft and of the contralateral control bone were embedded in methylmeta- and sawn into sections of 80 μm Films were exposed with a Machlett AEG 50 tube at 10 kV 1 for 1 s at a focus–object distance of 20 cm

The *radiographic bone appearances* were g as follows (cf PAAVOLAINEN et coll 1978 Fi

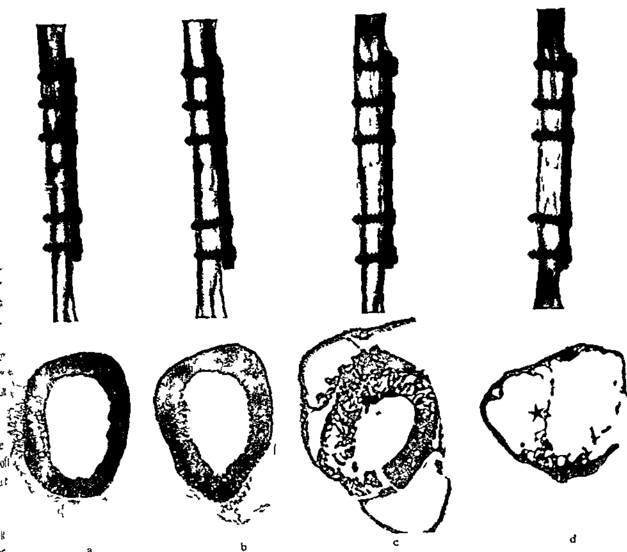
a) New bone formation around the screws
- – None
- \+ Endosteal bone around the screws
- ++ Endosteal and periosteal bone arou screws the thickness of the new being less than half the thickness cortex
- +++ Endosteal and periosteal bone exce half the thickness of the cortex

b) New bone formation around the plate
- – None
- \+ *Slight bone formation*
- ++ Bone to the level of the plate
- +++ Bone rising above the level of the pl

c) Periosteal reaction opposite the plate
- – None
- \+ Slight periosteal new bone
- ++ Subperiosteal new bone less than thickness of the original cortex in sections an external layer of perio bone
- +++ Subperiosteal new bone exceeding thickness of the original cortex in c sections a marked double layer conf tion

d) Resorption in cortical host bone under the
- – None
- \+ Slight decrease in cortical thickness
- ++ Thinning of cortex less than half the th ness of normal bone patchy porotic pearance of the bone
- +++ Marked porosity and thinning more half the thickness of normal cortex

e) Incorporation of the graft
- – None
- \+ Visible periosteal or interfragmentary bone connecting the graft
- ++ Bone lamellae traversing the osteo
- +++ Continuous bony cortex over both h- *graft interfaces*



ig 3 Cortical bone transplant after rigid plate fixation and orresponding cross-sections of the graft (The plate is situated o the right of the graft) a) After 3 weeks Periosteal new bone ormation around the graft in the cross section beginning en argement of the haversian canals in the opposite cortex and ewly formed subperiosteal bone b) After 6 weeks Primary bone ealing in the cross section enlargement of the haversian canals c) After 12 weeks Porotic transformation of the host bone and the proximal graft in the cross section marked double layer d) After 36 weeks Marked porosity of the cortical host and graft bone underlying the implant in cross section almost total resorption of the old cortex (marked with an asterix) new subperiosteal bone cuff enlarging the medullary canal

) Resorption of the graft

- – None
- \+ Slight porosity of the graft
- ++ Porosity and thinning of the cortex of the graft less than half the thickness of normal cortex
- +++ Marked porosity and thinning of the cortex of the graft more than half the thickness of normal cortex

Results

The healing and remodelling of the cortical and cancellous grafts are exemplified in Figs 3 and 4 The radiologic features assessed according to the criteria mentioned are summarized in the Table

New bone formation around the screws A slight endosteal reaction to the screws appeared already after one week in both graft series The periosteal reaction around the screws increased up to 12 weeks with a tendency to be more prominent in the cancellous graft specimens Towards the end of the experiment the newly formed bone condensed into a dense juxtacortical bone collar which united with the periosteal reaction opposite the plate

New bone formation around the plate Three weeks after the operation new bone had formed around the implant in half of the cortical and in

Table

Summary of radiographic changes in bone grafts after rigid plate fixation

Time after operation (weeks)	New bone formation around the screws		New bone formation around the plate		Periosteal reaction opposite the plate		Resorption in cortical bone under the plate		Incorporation of the graft		Resorption of the graft	
	Cortical	Cancellous	Cortical	Cancellous	Cortical	Cancellous	Cortical	Cancellous	Cortical	Cancellous	Cortical	Ca[illegible]
1	7–		7–	7–	7–	4–	7–	7–	6–	7–	7–	7
	5+	7+				3+			1+			
3			4–	1–		1–	4–	5–	2–	1–	8–	5
	5+	1+	4+	2+	6+	1+	4+		3+	4+		
	3++	4++		2++	2++	3++			3++		2–	6
6			3+	4+	3+	3+		6+		4+	3+	1
	5++	6++	2++	2++	2++	4++	5++	1++	5++	3++		
		1+++		1+++								1
12			2+	6+	2+	5+		1+		1+	4+	4
	5++	6++	4++	1++	3++	3++	6++	8++	6++	7++	3++	4
	2+++	3+++	1+++	2+++	2+++	1+++	1+++		1+++	1+++		
24			5+	4+	2+	1+		1+				
	6++	7++		3++	4++	6++	4++	6++		2++	5++	5
			1+++				2+++		6+++	5+++	1+++	
36			5+	7+	3+							3
	5++	7++			2++	7++	2++	2++		1++	2++	4
							3+++	5+++	5+++	6+++	3+++	
52			1+		1+							1
	2++	4++	1++	3++	1++	4++	1++	4++		1++	1++	3
		1+++		2+++		1+++	1+++	1+++	2+++	4+++	1+++	1

almost all cancellous graft specimens In the cancellous bone graft series the reaction around the plate was greatest at 6 weeks and in the cortical bone graft series at 12 weeks Later the periosteal reaction subsided

Periosteal reaction opposite the plate A slight periosteal reaction in the host bone occurred in the cancellous bone graft series already at one week in 3 of 7 specimens In the cortical bone graft series the periosteal new bone reaction was visible at 3 weeks These periosteal reactions were greatest in both groups at 12 weeks when a double cortical layer was observed in the cross sections of 5 of 7 specimens from the cortical bone graft series and in 4 of 9 samples from the cancellous bone graft series Towards the end of the experiment the periosteal bone condensed without increasing in thickness

Resorption in cortical host bone under the plate In the cortical bone graft series the first resorptive changes appeared at 3 weeks when the cortex of the host bone had slightly thinned in half of the specimens In the cancellous graft series the resor[illegible] of the host bone did not start until 6 weeks [illegible] the operation In both series the resorption first [illegible] curred in the proximal part of the host bone [illegible] it exceeded that of the distal part in all group[illegible] cross section specimens the resorption began [illegible] endosteally and progressed outwards in the cor[illegible] wall At 36 and 52 weeks the cortex was al[illegible] completely resorbed under the plate in half of [illegible] animals in both series

Incorporation of the graft Three weeks after [illegible] operation incorporation of the graft was visib[illegible] 6 of 8 cortical bone graft specimens and in 4 [illegible] cancellous bone graft samples At this time [illegible] osteotomies healed predominantly through p[illegible] osteal bone formation In 12 weeks all the os[illegible] tomies had healed but remnants were still visib[illegible] 6 of 7 cortical bone grafts and in 8 of 9 cancel[illegible] bone grafts In all cases the distal host-graft [illegible] face remained visible longest From 24 to 52 wee[illegible] both types of grafts were completely incorpora[illegible]

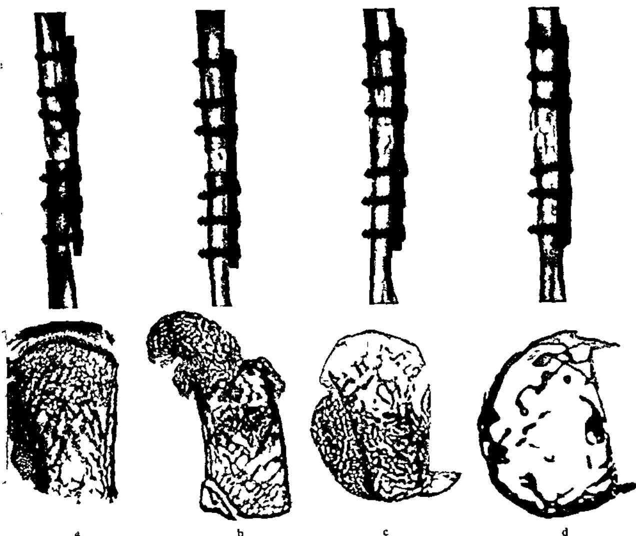


Fig 4 Cancellous bone transplant after rigid plate fixation and corresponding cross-section of the graft a) After 3 weeks periosteal new bone around the screws in the cross section periosteal new bone b) After 6 weeks Primary bone healing evident porosity of the graft in the cross section eccentric subperiosteal new bone formation c) After 12 weeks Thinning of the cortical host bone porosis of the host bone and the proximal graft condensed subperiosteal new bone which in the cross section is remodelling to a new tubular bone d) After 36 weeks Marked porosity of the host bone and the graft similar to the cortical graft series in the cross-section a new thin walled tubular bone

Resorption of the graft The resorption of the cortical graft first appeared after 6 weeks as a mild thinning and porosity in the cortex of the graft while that of the cancellous graft was not observed until 12 weeks after the operation This resorption always began in the proximal part of the graft and had a patchy porotic appearance with a marked thinning of the subendosteal cortex In specimens examined later the resorption was more marked in the graft than in the surrounding host bone

Discussion

The results show that with rigid plating both cortical and cancellous interposition grafts mend by primary bone healing that incorporation of both grafts is followed by progressive remodelling of the graft and the host bone and that this remodelling causes cancellous transformation and thinning of the cortex both in the graft and in the host bone

The amount of periosteal callus is influenced by the stability of the osteosynthesis (WIESER 1964 ANDERSSON 1965 HUTZSCHENREUTER et coll 1969 RÜEDI & ALLGÖWER 1974) and the degree of periosteal (KÜNTSCHER 1967 OLERUD & DANCKWARDT LILLIESTRÖM TRUETA 1974) or medullary (RICHANY et coll 1965 DANCKWARDT LILLIESTRÖM 1970) trauma In the present series the periosteal reaction around the screws and the plate occurred slightly earlier in the cancellous graft than in the

cortical graft series which suggests that greater osteoinductive activity occurs in cancellous grafts

The radiographic healing of both graft types was basically the same The incorporation of the graft started at 3 weeks by periosteal new bone formation around the graft The healing was completed by bone bridges traversing the host–graft interface 6 to 12 weeks after both types of grafting In all cases the distal host–graft interface healed last This sequential mode of healing was also noted by ZUCMAN et coll (1968) in triple level fractures of rabbit tibiae stabilised with a medullary rod

The remodelling of the cortical host bone which gradually occurred after graft incorporation can mainly be attributed to the reactions provoked by rigid plate (PAAVOLAINEN et coll) Thus the resorption of the cortical host bone was similar to that reported in plated intact rabbit tibiofibular bone by SLATIS et coll (1978) and in plated osteotomies of rabbit tibiofibular bone by GÖRDES et coll (1975) A phenomenon not occurring in simple osteotomies but found in the present series was bone resorption later in both the distal part of the graft and the host bone (Figs 2c and 3c) This occurrence as well as the delayed healing of the distal host–graft interface is obviously due to a less abundant blood supply to this area (GÖTHMAN 1960 TRUETA)

The remodelling of both graft types was accomplished by the simultaneous subperiosteal condensation of new bone and the progressive resorption of the old bone matrix This mode of remodelling has previously been observed in bone grafts both with (ALBREKTSSON) and without (ENNEKING et coll) internal fixation Similar haversian remodelling also occurs after intramedullary reaming (DANCKWARDT LILLIESTRÖM) and in connection with rigid plate fixation (SLATIS et coll) and it is obviously a common feature in cortical bone undergoing repair

The tibiofibular bone including the graft had an increased over all diameter a widened medullary canal and a thinned porotic cortical wall 36 to 52 weeks after the grafting procedure The radiographically visible resorption was more marked in the bone grafts than in the host bone Thus the uneventful healing of the grafts after rigid plate fixation seems to be counterbalanced by untoward structural changes in the cortical bone underlying the rigid metallic implant

Recent observations (P WARIS in progress) show that the torque strength of the grafted bone increases during the healing of the graft but then diminishes This phenomenon suggests that after graft[illegible] cedures combined with rigid plate fixation th[illegible] plants should remain in place until healing is [illegible] pleted but should be removed before the delet[illegible] effects of the implant have caused weakeni[illegible] bone However further experiences are need[illegible] fore the optimum time for implant removal c[illegible] determined

SUMMARY

Cortical and cancellous interposition grafts wi[illegible] plate fixation in the tibiofibular bones of 130 rabb[illegible] followed radiographically for one year The ca[illegible] grafts healed earlier but by 12 weeks both graft t[illegible] been incorporated the distal host–graft interface be[illegible] last to heal Progressive cancellous transformatio[illegible] the graft and host bone led to an increased over-a[illegible] diameter a widened medullary canal and a thinned p[illegible] wall

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RADIOLOGIC EVALUATION OF THE PROGRESSION OF RHEUMATOID ARTHRITIS

A DE CARVALHO H GRAUDAL and B JØRGENSEN

The purpose of this report is to survey the degree rheumatoid joint involvement based on radio aphy of all limb joints and to describe the relation ip between the joint involvement and the duration f the disease Previous reports have been based on idiography of selected joints It seems that no in estigations have been carried out which show by niform criteria to which extent a particular joint of group of patients is affected by the rheumatoid rocess

Material and Methods

The series consisted of 149 females and 39 males with classical or definite rheumatoid arthritis (ROPES t coll 1958) of the adult type The mean age of the emales at the onset of the disease was 38 1 years range 14–74) that of the males 42 years (range 17–62) The patients had been hospitalized in a specialized rheumatology unit and afterwards fol lowed for periods of 3 to 12 years

At least two radiographic examinations had been performed on each patient at an interval of at least 3 years On average each patient was examined 3 5 times (range 2–7) and with few exceptions radiography of all the limb joints was performed on at least 2 occasions A total of 661 skeletal examina tions were performed of these were 429 complete Affections of the cervical spine and the sacroiliac joints will be reported separately because they present special problems All films were evaluated by the same author (A C) without knowledge of clinical findings The joint involvement was classi fied by grades 0 to 5 by comparison with the standard films of LARSEN et coll (1977) and ac cording to the following definitions

- Grade 0 normal findings
- Grade 1 slight abnormality including periarticular soft tissue swelling juxta articular halis teresis possibly with slight narrowing of the joint space
- Grade 2 early but definite abnormality consisting of bone erosion and distinct narrowing of the joint space Erosion is obligatory ex cept in the weight bearing joints
- Grade 3 medium destructive abnormality with marked narrowing of the joint space and bone erosion also in weight bearing joints
- Grade 4 severe destructive abnormality Only minor parts of the articular surfaces re main
- Grade 5 mutilating lesions

An example of staging of the same joint at differ ent times appears in Fig 1 Although the standard films of LARSEN et coll illustrate regions e g radiocarpal and carpal joints in the present series each joint was evaluated separately with the excep- tion that the carpal joints the talar joints (subtalar calcaneo-cuboideal and talo-navicular) and the mid tarsal joints (including the tarso-metatarsal joints)

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Fig 1 Staging of the same joint at different dates

Table 1

Example of mapping the condition of one joint (right wrist) by means of absolute counts and relative frequencies of joint involvement by grades 0 to 5 at a given time after the onset of disease

Years from onset	Grade 0	1	2	3	4	5	Total
1	5	18	14	0	0	0	37
	13 5	48 6	37 8	0	0	0	6 2
2	0	8	13	3	0	0	24
	0	33 3	54 2	12 5	0	0	4 0
3	3	12	16	4	2	0	37
	8 1	32 4	43 2	10 8	5 4	0	6 2
4	4	11	20	8	1	1	45
	8 9	24 4	44 4	17 8	2 2	2 2	7 5
5–6	1	12	36	25	3	2	79
	1 3	15 2	45 6	31 6	3 8	2 5	13 2
7–8	2	7	32	20	10	3	74
	2 7	9 5	43 2	27 0	13 5	4 1	12 3
9–10	1	10	21	17	16	5	70
	1 4	14 3	30 0	24 3	22 9	7 1	11 7
11–12	0	4	16	15	11	5	51
	0	7 8	31 4	29 4	21 6	9 8	8 5
13–14	0	5	9	12	15	3	44
	0	11 4	20 5	27 3	34 1	6 8	7 3
15–16	0	2	10	7	15	5	39
	0	5 1	25 6	17 9	38 5	12 8	6 5
17–18	0	0	7	2	18	4	31
	0	0	22 6	6 5	58 1	12 9	5 2
19–22	0	0	3	8	12	7	30
	0	0	10 0	26 7	40 0	23 3	5 0
23≤	0	0	2	10	12	15	39
	0	0	5 1	25 6	30 8	38.5	6 5
Total	16	89	199	131	115	50	600
	2 7	14 8	33 2	21 8	19 2	8 3	100 0

Table 2

Joints that may be grouped without significant loss of information in the description of the progression of the disease. The right and left sides have been grouped together in all cases

Arms and hands	Legs and feet
Shoulder and acromioclavicular	Hip
Elbow	Knee
Wrist and carpus	Ankle
Carpometacarpal joint 1	Tarsus
Carpometacarpal joints 2–5	Midtarsal joints
Metacarpophalangeal joint 1	Metatarsophalangeal joint 1
Metacarpophalangeal joints 2–5	Metatarsophalangeal joints 2–5
Proximal interphalangeal joints 2–5	Proximal interphalangeal joints
Distal interphalangeal joints 2–5	Distal interphalangeal joints
Interphalangeal joint of the thumb	Interphalangeal joint of great toe

ere regarded as units. Satisfactory control of the formation has been effected by random sampling. he result has been subjected to electronic data rocessing.

Results

The results have been recorded in a table for each f the 86 joints examined. An example is given in able 1. It shows the percentage of joints which was nvolved by grades 0 to 5 at a given time after the nset of the disease.

An analysis of the involvement of individual joints howed that some joints could be grouped together without any essential loss of information due to a uniform progression (Table 2). The groups also include the corresponding joints of the right and left side.

In Figs 2 and 3 the distribution of the lesions is related to the duration of the disease. The figures summarize the classifications of 50 872 joints or joint units. The curves indicate the limits between the different grades for each group of joints so that the areas between the curves express the relative frequency of each grade. The frequency of joint involvement of grade 2 or higher after one, 4, 7–8 and 11–12 years appears in Table 3. The frequency of for example, grade 4+5 is not necessarily increasing because different patients appear at different times. In several groups of joints the progression of the disease never ceased.

Some special features appearing within some of the groups of joints should be mentioned. The involvement of the second and third carpometacarpal joints, right and left, was more severe than that of the first, fourth and fifth joints. The second and third metacarpophalangeal joints were more often affected than the fourth and fifth joints and the involvement of the first metacarpophalangeal joint was still smaller. The involvement of the right second and third metacarpophalangeal joints was more marked than that of the left joints.

Regarding the proximal interphalangeal joints of the left hand, the degree of involvement increased from the fifth to the second joint, and the second joint was more involved than the corresponding joint of the right hand. On the right hand the third proximal interphalangeal joint showed the highest degree of involvement, and the third to fifth joints of the right hand were more involved than the corresponding joints on the left hand.

By contrast, the lateral metatarsophalangeal joints, especially the fifth, were more severely involved than the medial joints.

Discussion

The grading system of LARSEN et coll. has been found to provide satisfactory distinction between slight, definite, moderate, severe and mutilating rheumatoid joint involvement. Thus, it is useful as a tool for evaluating the progression of the disease, especially during longer periods, whereas a detailed description is necessary for diagnostic purposes and for evaluating the progression during the early period of the disease.

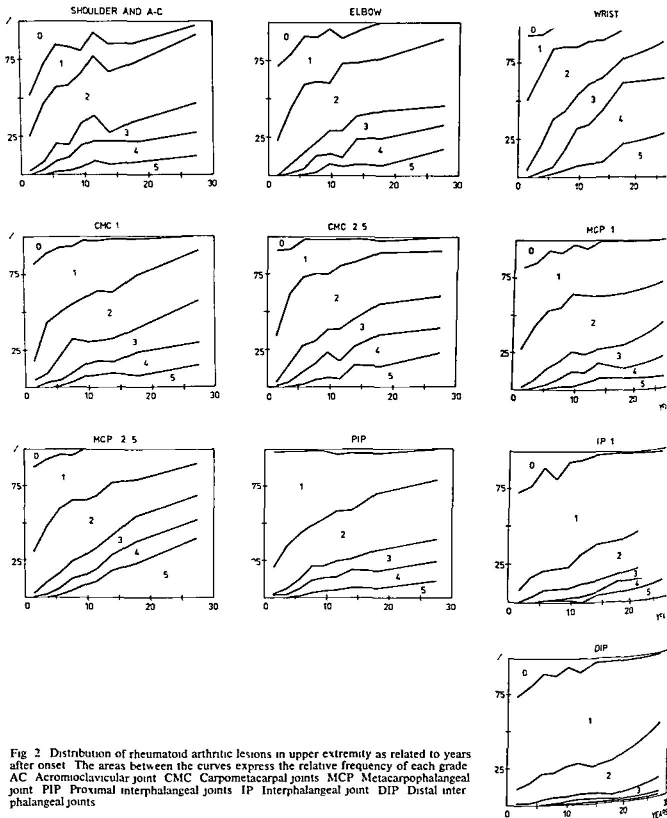
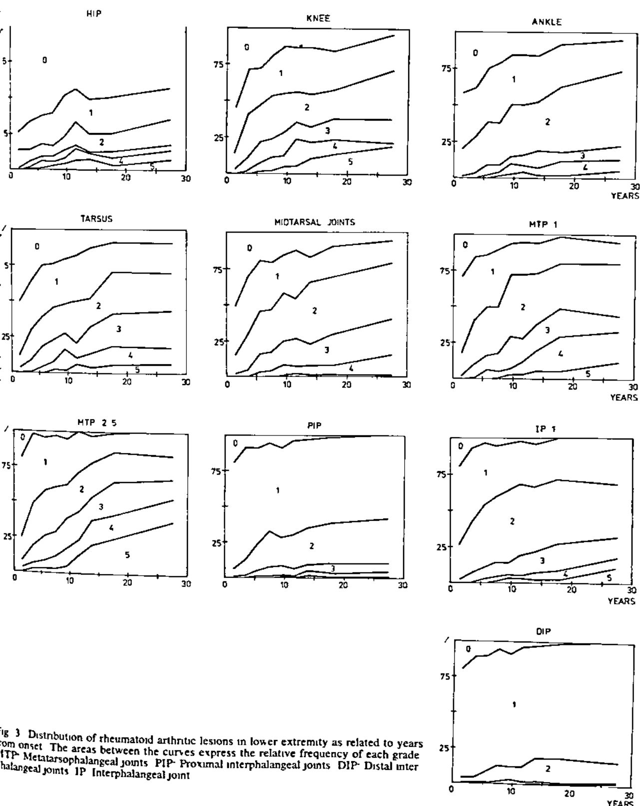


Fig 2 Distribution of rheumatoid arthritic lesions in upper extremity as related to years after onset The areas between the curves express the relative frequency of each grade AC Acromioclavicular joint CMC Carpometacarpal joints MCP Metacarpophalangeal joint PIP Proximal interphalangeal joints IP Interphalangeal joint DIP Distal interphalangeal joints

The patients in the present series are not representative of rheumatoid disease in the population but probably the series is fairly representative of rheumatoid patients referred to Danish hospitals This implies that the findings regarding single joints and joint groups may be used as a general prognostic estimate as far as hospitalized patients are concerned For example as regards any proximal interphalangeal joint of the fingers after 7 to 8 years of the disease the probability of grade 2 involvement



ig 3 Distribution of rheumatoid arthritic lesions in lower extremity as related to years om onset The areas between the curves express the relative frequency of each grade ITP- Metatarsophalangeal joints PIP- Proximal interphalangeal joints DIP- Distal inter halangeal joints IP Interphalangeal joint

vould be 27 per cent of grade 3 it would be 10 per ent and of grade 4 to 5 it would be 11 per cent It nay be estimated whether the course in a single atient is more or less serious than usual This pplies both to single joints and to the total progress of the disease Since in the majority of the cases all the joints of a patient have been examined at the same time it is justifiable to compare the amount of involvement of different joints or groups of joints after the same duration of the disease It seems that

Table 3

Percentage of joints with lesions of grade 2 or higher

	No classified joints	Years from onset											
		1			4			7–8			11–12		
	Grade	2	3	4+5	2	3	4+5	2	3	4+5	2	3	4+5
Upper extremity													
Shoulder/A C joint	2 251	23	2	0	37	6	3	39	8	11	39	17	22
Elbow	1 079	23	0	0	37	6	2	40	8	13	44	17	12
Wrist/carpus	2 415	47	4	0	47	16	4	42	25	18	78	27	34
CMC 1	1 228	17	5	0	34	6	4	23	22	10	33	13	18
CMC 2–5	4 924	31	2	0	47	12	3	45	15	15	47	22	17
MCP 1	1 210	26	2	0	36	5	1	36	12	7	39	13	17
MCP 2–5	4 908	29	2	0	38	8	2	41	12	12	35	14	19
PIP 2–5	4 905	18	1	1	29	4	2	27	10	11	34	11	14
DIP 2–5	4 906	10	1	0	14	1	0	14	4	1	21	4	4
IP	1 274	6	0	0	13	4	0	14	7	2	20	8	4
Lower extremity													
Hip	1 112	13	1	0	8	4	2	7	4	6	16	2	15
Knee	1 169	11	3	0	29	9	2	30	13	11	21	11	24
Ankle	1 071	18	1	0	25	3	0	29	5	4	34	7	9
Tarsus	1 071	9	3	0	21	8	1	23	15	8	29	11	11
Midtarsal joints	1 198	13	2	0	25	4	0	29	13	4	27	20	7
MTP 1	1 111	16	2	0	31	9	1	32	13	5	44	16	17
MTP 2–5	4 553	17	5	3	30	12	7	32	17	12	28	20	23
PIP 2–5	4 708	5	1	0	11	1	0	25	7	1	24	5	1
DIP 2–5	4 681	3	0	0	3	1	0	11	1	0	10	1	0
IP	1 198	24	2	0	35	7	1	45	10	5	49	14	5

A C Acromioclavicular joint CMC Carpometacarpal joints MCP Metacarpophalangeal joints PIP Proximal interphalangeal joints DIP Distal interphalangeal joints IP Interphalangeal joint MTP Metatarsophalangeal joints

an estimate of progressive involvement of one joint should preferably be viewed in the light of the state of other joints When the prognosis of single joints is analysed the finding may vary according to a casual composition of the patient group especially if the group is not large

It is not extraordinary that the general trend of the present findings concord with the opinion generally held Regarding some joints the findings have been in accordance with those reported in other series proximal interphalangeal joints of the hand (JACOBY et coll 1973 FLEMING et coll 1976 VAN DAM 1964) knees (JACOBY et coll SOILA 1958 SOSMAN 1964) talocrural joints (FORESTIER 1964) tarsal and midtarsal joints (FORESTIER ANSELL 1964) metatarsophalangeal joints of the feet (BROOK & CORBETT 1977 SOILA FLETCHER & ROWLEY 1952 MARTEL 1968) As regards some other joints other authors have found a lower or higher degree of involvement acromioclavicular joints (MEIJERS 1964) humeroscapular joints (DE SÈZE et coll 1964 bows (FLEMING et coll) proximal interphala joints of the hands (BROOK & CORBETT FLET & ROWLEY) hips (JONSSON 1961 KELLGREN talocrural joints (FLEMING et coll SOILA L KAINEN et coll 1977) The discrepancies ma explained by the variability of the disease

It is not known why some joints are more oft more severely affected by rheumatoid arthritis others At present it is not possible to formul hypothesis for the localization and progressio this disease based on joint anatomy vascula chemistry function or temperature Local fac are possibly not the only ones However a f exact knowledge of the appearances of the dyna rheumatoid joint involvement seems to be impor for an understanding of some of the factors determine a predisposition to rheumatoid invo ment and progression

The purpose of radiographic examination

-umatology is not only to be diagnostic but also form a basis for the therapeutic strategy and for evaluation of therapeutic results and the prog sis Radiography reflects biologic processes ich do not always conform to the social conse _ences of the disease

SUMMARY

The severity of rheumatoid arthritis in 20 groups of limb nts was evaluated by means of 661 skeletal radiologic aminations on 188 patients The severity of the disease is classified by grades 0 to 5 in accordance with LAR N S grading system and was related to the duration of e condition The result differs at several points from sults in other surveys

ACKNOWLEDGEMENTS

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OM THE DEPARTMENT OF DIAGNOSTIC RADIOLOGY AALBORG SYGEHUS SYD DK 9199 AALBORG DENMARK

ARTHROGRAPHIC DIAGNOSIS OF RUPTURED CALCANEOFIBULAR LIGAMENT

I A new projection tested on experimental injury post mortem

M VUUST

Arthrography of the ankle in cases of acute distor ns was introduced by WOLFF (1940) and has been particular value for the diagnosis of rupture of the eral ligaments of the talocrural joint (GLASTRUP 65 BROSTRÖM et coll 1965 PERCY et coll 1969 APLES 1975 SPIEGEL et coll 1975 LINDHOLMER coll 1978 PRINS 1979) Most frequent are isolated pture of the anterior talofibular ligament and com ned rupture of this ligament and the calcaneofibu r ligament Rupture of the posterior talofibular gament is infrequent (BROSTRÖM 1965) Isolated ipture of the calcaneofibular ligament has been re orted by PRINS but was not found by BROSTRÖM or INDHOLMER et coll in their series

The usefulness of arthrography for the diagnosis f acute ruptured anterior talofibular ligament was stablished by BROSTRÖM et coll and LINDHOLMER t coll found that 97 per cent of the pathologic arthrographies demonstrated rupture of this liga nent However it is difficult to determine whether upture of the calcaneofibular ligament has also oc urred Several attempts to find valid criteria for this diagnosis have been made

BROSTRÖM et coll found that contrast filling of the peroneal sheath was a reliable indication of rupture of the calcaneofibular ligament as did FORDYCE & HORN (1972) and PERCY et coll On the other hand SPIEGEL et coll STAPLES LINDHOLMER et coll (PRINS considered such a finding less reliable In 61 cases of calcaneofibular ligament rupture operated upon filling of the peroneal sheath occurred in only 31 (LINDHOLMER et coll)

PERCY et coll based their criteria on the size and location of the contrast leakage at the lateral mal leolus They suggested that a leakage anterior to the malleolus indicated rupture of the anterior talofibu lar ligament alone whereas enlargement of the leak age and extension laterally indicated rupture of both lateral ligaments In the 61 cases of calcaneofibular ligament rupture reported by LINDHOLMER et coll the diagnosis was made in only 37 using the criteria of PERCY et coll

Other indications of rupture of both lateral liga ments have been suggested poor contrast filling of the recesses of the talocrural joint size of the leak age measured using an index (LINDHOLMER et coll) and recording of low pressure at the injection of the contrast medium (PERCY et coll SPIEGEL et coll) but none of these have gained a wider use

A new projection for the diagnosis of rupture of the calcaneofibular ligament is described in the pres ent report It has been tested in arthrography of experimental post mortem lesions

Previously projections at right angles to the lower leg have been used in arthrography of the ankle joint These include antero posterior and lateral pro-jections and antero posterior projections with 20 to 30° lateral and medial rotation of the foot On such views it may be difficult to observe the exact posi tion of the leakage at the lateral malleolus because of superimposition of bones and intra articular con trast medium

Therefore it was aimed at finding a projection which demonstrated the ligament without such a

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Fig 1 Position of the foot for the oblique axial projection

superimposition of bone intraarticular contrast medium or of anterior leakage through a rupture of the anterior talofibular ligament This projection is now described

Material and Methods

The investigation was performed on 14 ankle joints from 9 fresh cadavers (average age 51 years range 34 to 74) without lesions of the extremities The normal trauma mechanism was imitated by manual forced supination of the foot In case of fracture caused by the experimental trauma ankle was excluded from the series

Arthrography was performed by injection of meglumin iothalamate (Conray meglumin 78%) teromedially into the talocrural joint Giemsa stain was added to the contrast medium in order compare the leakage visible on the dissected specimen with that on the arthrographic film T jections were used an antero posterior a lateral a new one an oblique axial projection

The patient is in supine position with th maximum bent The hip is rotated 40° laterally the foot 25° laterally with the plantar surface of foot kept in horizontal position The central directed 50° from the vertical plane cranially centered in the malleolar fossa (Fig 1)

A drawing of the oblique axial projection is sented in Fig 2a Exposures with metal markers both ends of the calcaneofibular ligament shown the position of the ligament in this projection It extends from the anterior part of the lateral leolus through the malleolar fossa to the calcaneus and inserts on a prominence always visible in projection

Evaluation of the films The antero posterior lateral views were evaluated using the criteria scribed by PERCY et coll Three types were distinguished

Type I Anterior rupture of the capsule with injury to the lateral ligaments Contrast medium located anterior to the tibia

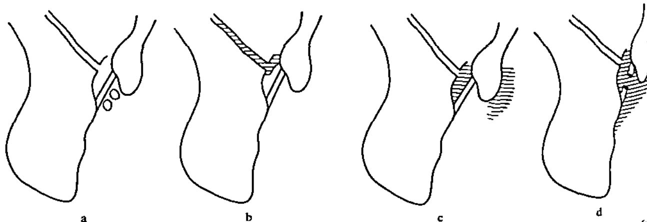
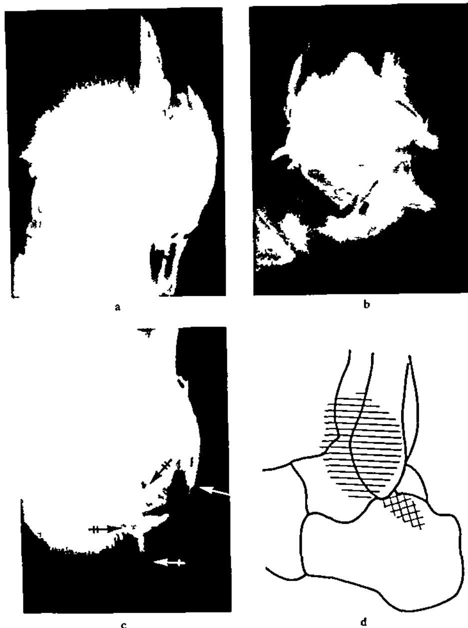


Fig 2 Oblique axial projection a) The malleolar fossa is located between the calcaneus and fibula The calcaneofibular ligament traverses the fossa with the sheath of the peroneus tendon situated just behind b) Normal arthrography Contrast medium in the posterior calcaneotalar joint No injury to the lateral ligaments c) Maximum leakage from a rupture of the anterior talofibular ligament No contrast medium in the malleolar fossa behind the intact calcaneofibular ligament If medium is present in the anterior part of the fossa it often has a straight border to the calcaneofibular ligament d) Leakage from a rupture of both lateral ligaments Contrast medium behind the calcaneofibular ligament Medium lateral to the malleolus may be absent



g 3 Total rupture of both lateral ligaments a) A p b) lateral ew assessed to have the contrast leakage mainly anterior to the teral malleolus c) Oblique axial view Contrast medium lateral the malleolus (→) Separated from this medium close to the lcaneus (↔) its posterior part situated behind the calcaneofibular ligament (between ↔) d) Drawing of the dissected ankle (same projection as in b) Two separated regions of contrast leakage The lined area is the leakage from the ruptured talofibular ligament and the crossed area is located around the ruptured calcaneofibular ligament

Type II Rupture of the capsule and the anterior alofibular ligament Contrast medium is situated anerior to the lateral malleolus

Type III Both lateral ligaments ruptured Conrast medium is situated laterally and anterior to the ateral malleolus occasionally spreading upwards along the fibula and often situated around the tip of the fibula

The oblique axial view was evaluated according to the criteria defined in Fig 2 b–d

All films were evaluated before the dissection

Dissection was performed in order to assess the types and extension of the lesions and the leakage of the contrast medium The tendons and the peroneal sheath were removed and the capsule and ligaments on the lateral aspect of the ankle joint were exposed

Results

At the dissection rupture of the anterior talofibular ligament was found in 7 cases and of both lateral



a b c

Fig 4 Rupture of both lateral ligaments a) A p b) lateral view Slight leakage mainly anterior to the lateral malleolus considered Percy type II c) Oblique axial view Leakage extends behind the calcaneofibular ligament (++)

ligaments also in 7 cases Using the criteria of PERCY et coll rupture of the anterior talofibular ligament was diagnosed correctly in all cases with this lesion but of the cases with rupture of both lateral ligaments only the anterior one was considered ruptured in 5 cases the other 2 cases were diagnosed correctly On the oblique axial film using the criteria defined in Fig 3 2 b–d all cases with rupture of anterior talofibular ligament and all cases with rupture of both lateral ligaments were diagnosed correctly

All seven ruptures of the calcaneofibular ligament were total Five of these were Z ruptures i e a lesion where some of the fibers of the ligament are broken anteriorly and the rest posteriorly At first sight the lesions were thought to be partial ruptures The fibers were held so close together by the peritendinous connective tissue that the ligament resisted even rather severe strain

In one case of rupture of the anterior talofibular ligament a few fibers had remained intact

The peroneal sheath was filled in all cases of rupture of both lateral ligaments No contrast filling occurred if only the anterior talofibular ligament was ruptured The appearance of total rupture of the lateral ligaments is illustrated in Fig 3 On the post mortem films the leakage had a more well defined outline and less of the characteristic flame shape than on films exposed in vivo

Discussion

The extension and position of the leakage of [illegible] trast medium assessed on the antero posterior [illegible] lateral films are dependent not only upon ruptu[illegible] the calcaneofibular ligament This may explain [illegible] LINDHOLMER et coll applying the criteria of PE[illegible] et coll found 8 false positive and 24 false nega[illegible] arthrographies in the 61 cases with ruptures of c[illegible] caneofibular ligament operated upon

The anterior talofibular ligament is strongly [illegible] to the capsule of the talocrural joint Therefore [illegible] rupture of the ligament is always followed by a r[illegible] ture of the capsule Consequently a leakage a[illegible] to the lateral melleolus nearly always indicates [illegible] rupture of the anterior talofibular ligament (Br[illegible] STRÖM et coll LINDHOLMER et coll) It is diffic[illegible] to distinguish this lesion from the pure a ter[illegible] rupture of the capsule but since such a rupture [illegible] infrequent the problem is of little practical impor tance

The calcaneofibular ligament is a cord like a[illegible] much thinner ligament and in contrast to the an terior talofibular ligament not closely related to th[illegible] capsule *A varying portion of the capsule* betwee[illegible] the ligaments may rupture together with the anteri[illegible] talofibular ligament without simultaneous ruptur[illegible] of the calcaneofibular ligament Consequently th[illegible] contrast leakage may vary both in extension a[illegible] position in the isolated rupture of the anteri[illegible]

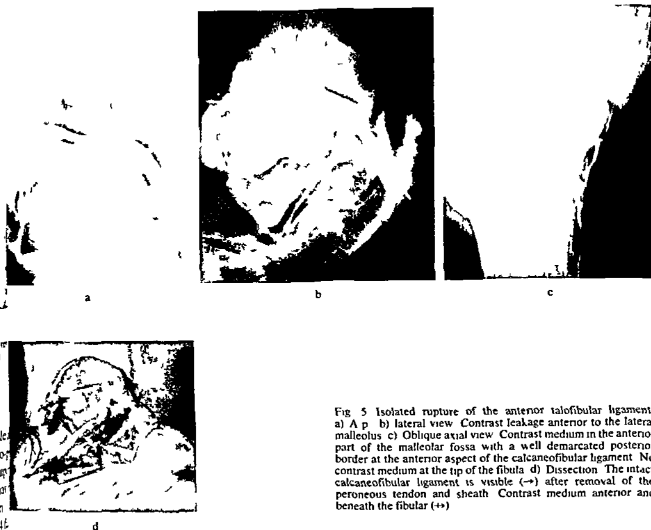


Fig 5 Isolated rupture of the anterior talofibular ligament a) A p b) lateral view Contrast leakage anterior to the lateral malleolus c) Oblique axial view Contrast medium in the anterior part of the malleolar fossa with a well demarcated posterior border at the anterior aspect of the calcaneofibular ligament No contrast medium at the tip of the fibula d) Dissection The intact calcaneofibular ligament is visible (→) after removal of the peroneous tendon and sheath Contrast medium anterior and beneath the fibular (↠)

lofibular ligament The volume of the talocrural joint the lesion of the surrounding soft tissue and the habitual condition of the tissues may also influence the extension of the contrast medium Therefore the extension of the leakage is not a reliable indication of the rupture of the calcaneofibular ligament Extensive leakage may occur in cases of rupture of the anterior talofibular ligament alone and small leakage in rupture of both lateral ligaments (Fig 4) On this figure it is difficult to decide from the antero-posterior and lateral films the posterior extension of the contrast medium Thus an isolated rupture of the anterior talofibular ligament may be suggested The correct diagnosis was obtained when viewing the position of the contrast medium in relation to the calcaneofibular ligament on the oblique axial film

The position of the leakage as determined from the antero-posterior and lateral films is not a reliable indicator of calcaneofibular ligament rupture either Most often the contrast medium spreads upwards along the fibula because distally the skin is more firmly attached to the bone It seldom spreads more than one cm distally beyond the tip of the fibula If the calcaneofibular ligament is ruptured the contrast medium can spread backwards from the ruptured capsule and beneath and medially to the tip of the fibula If the ligament is intact the medium stops at the ligament (Figs 5 6) In such cases it may spread laterally and backwards around the lateral aspect of the fibula and the intact calcaneofibular ligament It is not possible to distinguish these two types of leakage on the antero-posterior or lateral films For this distinction the oblique axial film is necessary because only the contrast medium beneath the tip of the fibula in the malleolar fossa indicates a rupture of the calcaneofibular ligament

This investigation has shown that the contrast medium in the malleolar fossa is easily observed on the oblique axial film The results confirm that a



Fig 6 Two oblique axial exposures from the same case with isolated rupture of the anterior talofibular ligament a) Leakage in the malleolar fossa with a sharp posterior outline b) Piece of lead indicates the position of the calcaneofibular ligament

leakage in the fossa behind the position of the calcaneofibular ligament indicates a rupture of the ligament However this experimental investigation was performed post mortem and clinical evaluation of the validity of the criteria defined in Fig 3 is needed The results of such an evaluation will be given in a forthcoming report

Contrast filling of the peroneal sheath was a reliable criterion on rupture of both lateral ligaments This is at variance with the in vivo findings of several authors (LINDHOLMER et coll STAPLES and SPIEGEL et coll) The reason for this discrepancy is not clear

It is interesting to note that 5 of 7 total calcaneofibular ligament ruptures were Z ruptures Neither the report by BROSTRÖM nor by RUTH mentions this type of lesion Maybe it is only found at post mortem trauma on the other hand it cannot be excluded that it is an overlooked type of lesion The latter possibility is supported by the fact that thorough dissection is needed to enable detection of the lesion Partial ruptures may in fact have to be regarded and treated as if they were total ruptures

SUMMARY

A new projection oblique axial is recommended for arthrography of the acute sprained ankle for the correct diagnosis of a ruptured calcaneofibular ligament Its r[illegible] is experimentally confirmed

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ACTA RADIOLOGICA

DIAGNOSIS 1980

CISTERNAL ABNORMALITIES PRODUCED BY CLINICAL TUMOURS IN THE POSTERIOR CRANIAL FOSSA

II Fourth ventricle tumours

M LINDQVIST

The pneumographic diagnosis of fourth ventricle tumours was originally based only on ventriculography (LYSHOLM 1935) LINDGREN & DI CHIRO (1953) discussed distortions of the aqueduct and the quadrigeminal cistern in cases with different tumour locations in the posterior cranial fossa describing among other things the posterior rotation of the inferior part of the quadrigeminal plate when a tumour is causing dilatation of the fourth ventricle LILIEQUIST (1963) pointed out that when intraventricular tumours protrude through the foramen of Magendie the inferior pole of the tumour can be demonstrated with encephalography

MÖLLER (1974) on the basis of the origin and mode of growth of the tumours divided tumours within and adjacent to the fourth ventricle into 15 different groups For each group a detailed description was given of the pneumographic appearance of the fourth ventricle and the aqueduct as well as of some of the cisterns especially the pentonsillar spaces the vallecula and the pontine interpeduncular and quadrigeminal cisterns

In previous reports cisternal distortions produced by experimental tumours in the posterior cranial fossa (LINDQVIST & MÖLLER 1978 LINDQVIST 1978) and the pneumographic cisternal abnormalities in cerebellar tumours (LINDQVIST 1980a) were described The purpose of the present report is to present in a similar way the cisternal characteristics associated with tumours in the fourth ventricle

Definitions The orientation of the structures of the posterior fossa is that given by CORRALES & GREITZ (1972) and used previously (LINDQVIST & MÖLLER LINDQVIST 1978 1980a) implying that a beam direction parallel to the clivus is termed the axial projection For nomenclature and a schematic survey of the normal anatomy of the cisterns see LINDQVIST (1980a Fig 1)

Material and Methods

The material consisted of the intraventricular tumours from the same series of patients with posterior fossa tumours including the cerebellar tumours reported previously (LINDQVIST 1980a) examined by encephalography during the period 1969 to 1975 In all cases the position and type of tumour was confirmed at surgery or autopsy Patients previously operated upon in the posterior cranial fossa were not included

The pneumographic examination technique has been described previously (LINDQVIST 1980a) The initial lumbar encephalography in cases with unsatisfactory passage of gas to the ventricular system was usually supplemented by ventriculography

The total number of patients was 34 From these *4 were excluded 2 because the position of* the tumour could not be definitely established one because encephalography failed completely for technical reasons and in a fourth case the film material was lost The remaining 30 cases form the basis for the present report The sex and age distribution of the series appears in Fig 1 and the tumour classi*fication in Table 1*

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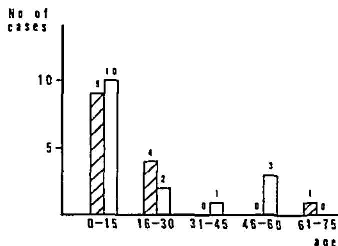


Fig 1 Sex and age distribution of 30 cases of intraventricular tumours of the fourth ventricle ▨ males ☐ females

As in the previous analysis of cerebellar tumours the position of the tumours was established by two experienced neuroradiologists who had access to all neuroradiologic examinations surgical and autopsy reports The tumours have been grouped in the positions given by MÖLLER However the cisternal distortions indicate that the paraventricular tumours originating from the posterior surface of the medulla oblongata are more closely related to tumours originating from the floor of the fourth ventricle than to cerebellar tumours They were therefore included in the present analysis while other paraventricular tumours were grouped together with the cerebellar tumours (LINDQVIST 1980a)

The tumours were divided into the following two main groups

(1) Tumours from the roof or walls of the fourth ventricle termed here *tumours from the roof* including the following tumour positions according to MÖLLER s classification Ib IIb IIIb and VIb

(2) Tumours from the floor of the fourth ventricle or from the posterior surface of the medulla oblongata inferior to the fourth ventricle termed here *tumours from the floor* including the following tumour positions according to MÖLLER s classification IV Vb 1 Vb 2 Vb 3 Vb 4

The distribution of the tumours in the two groups and also the distribution according to MÖLLER s classification is given in Table 2

The films were reviewed with respect to filling and distortion of different cisternal structures and also to filling and size of the ventricular system The findings were analysed in the same way as in the previous report on cerebellar tumours (LINDQVIST 1980a) Thus in order to facilitate data processing

Table 1

Classification of intraventricular tumours of the fourth ven in children and adults

Type of tumour	Children (0–15) years) No of cases	Adults (16 years or more) No of cases	Total No of cases	Per cent
Medulloblastoma	8	1	9	300
Juvenile astrocytoma	8	1	9	300
Ependymoma	3	4	7	233
Plexus papilloma	0	2	2	67
Exophytic glioma of the brain stem	0	2	2	6
Hemangioblastoma (Lindau)	0	1	1	33
Total	19	11	30	

Table 2

Intraventricular tumours of the fourth ventricle grouped according to their positions

Tumour position	Tumour positions (MÖLLER s classification)	No of cases
Tumours from the roof	Ib	1
	IIb	3
	IIIb	3
	VIb	3
Total		10
Tumours from the floor	IV	4
	Vb 1	5
	Vb 2	1
	Vb 3	1
	Vb 4	9
Total		20

all asymmetric tumours were treated as if the predominance was right sided

The peritonsillar spaces were often better filled in patients with tumours in the fourth ventricle than in those with cerebellar tumours Since a detailed analysis of these structures in tumours of the fourth ventricle was included in MÖLLER s report they have been given less attention in the present report

Results and Discussion

The frequency of demonstrable filling and the characteristic distortion of the most important cis

Table 3

…ling and distortion of the cisterna magna in fourth ventricle …ours Symbols and abbreviations a=anterior p=posterior …=superior i=inferior R=right L=left 0=no change (+) …imal change or increase +=moderate change or increase ++=marked change or increase (−)=minimal decrease …=moderate decrease −−=marked decrease open space= structure not possible to evaluate

…mour position	Fourth ventricle			
	Roof		Floor	
	Filling (%)	Distortion	Filling (%)	Distortion
…sterna magna				
… Extracranial part				
lat proj	100		95	
tonsillar herniation		+		(+)
a p displacement of cervical medulla		a(+)		p+
… Interhemispheric part				
lat proj	100		95	
s i diameter		−−		( )
Foramen of Magendie				
lat proj	70		30	
a p displacement		a+		p+
Vallecula axial proj	90		4[illegible]	
width		++		++
lateral displacement		0		0
Retrotonsillar spaces				
lat proj	70		35	
a p displacement		p++		p++
s i displacement		i++		i+
Cerebellomedullary fissures				
a. right side axial proj	80		30	
a p displacement		0		p(+)
lateral displacement		R(+)		R(+)
b left side axial proj	80		30	
a p displacement		0		p(+)
lateral displacement		L(+)		L(+)
7 Paravermian sulci axial proj	70		21	
width of inferior vermis		++		++
lateral displacement of inferior vermis		0		0

…ternal structures associated with tumours originating from the roof and from the floor of the fourth ventri…cle are summarized in Tables 3 4 and 5 Only struc…tures filled in at least 20 per cent of the cases and considered of value for locating the tumour or for comparing the cisternal distortions with those oc…curring in tumours with other locations in the pos…terior fossa have been included

Cisterna magna

Tonsillar herniation below the foramen magnum was present in 50 per cent of the cases with tumours from the roof but in less than 20 per cent of those with tumours from the floor (Table 3)

A tumour pole extending below the foramen magnum was present in 10 per cent of the tumours from the roof but in almost half of the tumours from the floor

Tonsillar herniation was thus much less common in cases with intraventricular tumours of the fourth ventricle than in the case of cerebellar tumours In some cases it was difficult to decide from the films whether a soft tissue structure below the foramen magnum was part of a tumour or a herniated tonsil As pointed out by MÖLLER in such cases it is impor tant to identify the position of the upper pole of the tonsil using as a guide the retrotonsillar spaces the posterolateral fissures and postero superior recesses of the fourth ventricle In addition the vallecula should be evaluated as a rule it is widened if the tumour grows out from the fourth ventricle into the cisterna magna via the foramen of Magendie

The cervical medulla was usually somewhat dis placed anteriorly below the foramen magnum but posterior displacement was also encountered This was especially the case with tumours from the roof in the vicinity of the fastigium (position II b accord ing to MÖLLER s classification) the posterior dis placement of the cervical medulla can then be assumed to be secondary to a marked anterior dis placement of the medulla oblongata

The interhemispheric part of the cisterna magna was usually compressed against the occipital crest However two important exceptions from this rule existed namely cases where a tumour or part of it was situated in the cisterna magna (positions IV and V b 3) In such cases the cisterna magna was usually markedly widened (Fig 2) as has also been de scribed by MÖLLER

Filling of the *foramen of Magendie* was more of ten associated with tumours from the roof than with tumours from the floor In the former situation an anterior displacement of the foramen of Magendie was usually present indicating compression or an terior displacement of the medulla oblongata while in the latter the foramen of Magendie was instead displaced posteriorly

The vallecula was widened in all assessable cases with tumours from the floor as well as with the majority of the roof tumours (Fig 3) In a few cases



a



b



c

Fig 2 Tumour from the posterior surface of the medulla oblongata (position IV) a b) Encephalography Only a small part of the tumour is visible (→) above the air fluid level in the markedly dilated cisterna magna c) Ventriculography lateral tomography The fourth ventricle is free from tumour except for a small indentation from below (↦) The supero inferior diameter of the interpeduncular cistern is markedly reduced (⊳→)

with tumours from the roof the width of the vallecula was normal or slightly decreased

When tumours were situated in the midline as a rule the vallecula was not displaced laterally In cases with asymmetric tumours both from the roof and from the floor a moderate lateral displacement of the vallecula towards the contralateral side was evident

The retrotonsillar spaces were often well demonstrated in both axial and lateral projections especially in the case of tumours from the roof In the lateral projection they were usually displaced posteriorly and inferiorly both in roof and in floor tumours the average inferior displacement being more marked in the former location

The retrotonsillar spaces are important indicators of the position of the superior posterior poles of the tonsils Deformity and displacement of each of the tonsils can be evaluated by analysing these spaces as well as the secondary fissures in the axial projection as emphasized by MÖLLER this is of importance for a detailed analysis of the origin and mode of growth of the tumours

The cerebellomedullary fissures which indicate the border between the tonsils and the medulla oblongata were separated both in the roof and in the floor tumours with the latter tumour location they were also slightly displaced posteriorly

The paravermian sulci which indicate the width of the inferior vermis were more often demonstrated in cases with tumours from the roof than in floor tumours Widening of the vermis was evident in both groups of tumours in all cases assessable (Fig 3a) In some cases with asymmetric

a

b

Fig 3 Tumour from the inferior part of the roof (position III b) Encephalography a) Axial tomography The vallecula is widened) Separation of the paravermian sulci (↔) indicates increased width of the inferior vermis b) Lateral tomography Tumour mole (↔) in the foramen of Magendie The interpeduncular cistern is compressed (>→)

Tumours a slight lateral displacement of the inferior vermis was observed this being a more common feature among the roof tumours

Medullary cistern

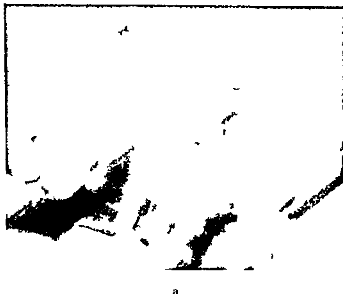
The premedullary part of the medullary cistern was markedly compressed in both groups of tumours (Table 4) In the axial projection *the lateral recesses* of the medullary cistern appeared bilaterally compressed both the a p and lateral extension these features which were present in a majority of cases in both groups of tumours are due to anterior displacement and increased width of the medulla oblongata The increase in width was as a rule more marked in cases with tumours from the floor than in those from the roof With tumours from the roof the medulla oblongata was compressed from behind and the a p diameter reduced with tumours from the floor the a p diameter of the medulla oblongata could seldom be evaluated

An increase in the transverse width of the medulla

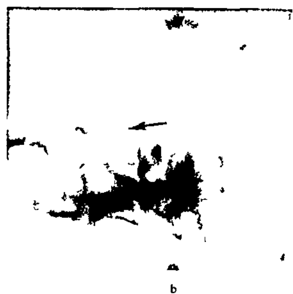
Table 4

Filling and distortion of the medullary cistern pontine cistern and the pontocerebellar cisterns in fourth ventricle tumours Symbols and abbreviations as in Table 3 Additional abbreviations Ra=right side rotated anteriorly Rp=right side rotated posteriorly

Tumour position	Fourth ventricle			
	Roof		Floor	
	Filling (%)	Distortion	Filling (%)	Distortion
Medullary cistern				
1 Premedullary part				
lat proj	30		50	
a p diameter		–		– –
2 Lateral recesses				
a right side axial proj	70		50	
a p diameter				– –
lateral extension		–		
b left side axial proj	90		50	
a p diameter		–		– –
lateral extension		–		–
3 Diameter of medulla oblongata				
a p diameter lat proj		–		
transverse diam axial proj		+		+ +
4 Lateral displacement of medulla oblongata axial proj		0		0
5 Rotation of medulla oblongata around axis parallel to clivus		0		0
Pontine cistern lat proj	90		80	
a p diameter		–		–
tendency of superior part of pons to recede from clivus		(+)		+
Pontocerebellar cisterns				
1 Right side axial proj	50		60	
width of lateral part		–		–
width of medial part		–		– –
2 Left side axial proj	40		80	
width of lateral part		–		–
width of medial part		–		– –



a



b



c

Fig 4 a b) Intraventricular tumour from the floor (position V b 1) Encephalography lateral tomography in the sitting position a) Before and b) after filling of the cisterns The superior part of the pons (→) recedes markedly from the clivus c) Tumour from the posterior surface of the medulla oblongata (position IV) Encephalography lateral tomography in the sitting position The pontine cistern is uniformly compressed and the anterior surface of the pons (+→) is approximately parallel to the clivus The tumour (#→) visible in the cisterna magna

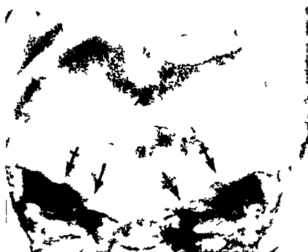
oblongata in the axial projection was not evident in some cases of lateral tumours from the roof especially in those with tumours originating from the lateral wall of the fourth ventricle (position VIb) In cases with an asymmetric tumour the medulla oblongata was also slightly displaced laterally Asymmetric tumours originating from the roof in the vicinity of the fastigium (position IIb) and the inferior part of the roof (position IIIb) could also cause an anterior rotation of the medulla oblongata on the tumour side

A p compression and increased width of the medulla oblongata was observed by MÖLLER in some patients with fourth ventricle tumour both in roof and in floor tumours

Pontine cistern

A moderate compression of the pontine cist[...] was encountered in both groups of tumours (Ta[...] 4) In approximately one third of the cases the [...]ferior part of the brain stem was compressed agai[...] the clivus while the superior part was displac[...] posteriorly in other words the superior part of t[...] pons receded from the clivus (Fig 4 a b) In t[...] remaining two thirds of the cases the anterior su[...]face of the pons was parallel to the clivus (Fig 4[...] but the two groups did not seem to differ in a[...] other respect for instance in the size type or po[...]tion of the tumours or the degree of hydrocephalu[...]

Compression of the pontine cistern is a recogniz[...] and important indication of tumour of the posteri[...]



a



b

ig 5 a) Intraventricular tumour from the floor (position V b 1) ncephalography axial view Symmetric compression of both ontocerebellar cisterns The medial parts (→) somewhat more ompressed than the lateral parts (+•) b) Asymmetric tumour from the roof with right-sided predominance (position III b) The right pontocerebellar cistern compressed both medially (→) and laterally (↦) the width of the left cistern normal both medially (⤚) and laterally (⊶)

ossa (DYKE & DAVIDOFF 1935 RUGGIERO 1957 LILIEQUIST) Posterior displacement of the superior part of the brain stem in some cases with fourth ventricle tumours was reported by MOLLER

Pontocerebellar cisterns

In both groups of fourth ventricle tumours the pontocerebellar cisterns were moderately compressed on both sides In cases with tumours from the floor the medial part of the cistern was usually more compressed than the lateral part (Fig 5 a) due to expansion of the brain stem In cases with roof tumours the degree of compression was usually the same medially as laterally and in the case of lateral or asymmetric tumours from the roof sometimes only the cistern on the tumour side was compressed (Fig 5 b)

Interpeduncular cistern

The average a p diameter of the interpeduncular cistern was not altered while the supero inferior diameter was reduced in both groups of tumours more so in cases with tumours from the roof (Table 5) On the other hand the superior displacement of the pons was somewhat more marked in cases with tumours from the floor The posterior part of the superior surface of the pons was slightly tilted in an upward direction in most cases in both groups

Changes in the supero inferior diameter of the interpeduncular cistern are due not only to the degree of supero inferior displacement of the pons but also largely to the width of the anterior part of the third ventricle i e to the presence of a widened supratentorial ventricular system (LINDQVIST 1980 a) The a p diameter of the cistern depends mainly on the degree of antero-posterior displacement of the brain stem The apparent discrepancy between the supero inferior diameter of the cistern and the degree of upward displacement of the pons in cases with tumours from the floor and from the roof (Table 5) can thus be explained by the fact that supratentorial ventricular dilatation was more marked in the latter group (Fig 6) Even though the average a p diameter of the interpeduncular cistern was normal great variations existed in both groups with cases of both increased and decreased a p diameter an increased a p diameter was noted particularly in the cases in which the superior part of the pons receded from the clivus

Ambient cistern

The circum mesencephalic parts were insufficiently filled in most of the cases particularly the infratentorial parts in cases with tumours from the roof The width of the supratentorial anterior part of the cistern was possibly slightly reduced on both sides in cases with tumours from the floor but otherwise no distortion of the circum mesencephalic parts of the ambient cistern was demonstrated (Table 5)

Table 5

Filling and distortion of the interpeduncular cistern ambient cistern and quadrigeminal cistern in fourth ventricle tumours Symbols and abbreviations as in Tables 3 and 4 Additional abbreviations fr=frontally sag=sagittally i a =inferior end rotated anteriorly i p =inferior end rotated posteriorly

Tumour position	Fourth ventricle			
	Roof		Floor	
	Filling (%)	Distortion	Filling (%)	Distortion
Interpeduncular cistern				
Lat proj	90		90	
a p diameter		0		0
s i diameter		–		–
s i displacement of pons		s(+)		s+
s i inclination of the posterior part of the superior surface of the pons		s(+)		s(+)
Ambient cistern				
Circum mesencephalic part axial proj				
a width of posterior part				
right side	30	0	35	0
left side	30	0	35	0
b width of anterior infra tentorial part				
right side	10		25	0
left side	10		25	0
c width of anterior supra tentorial part				
right side	20	0	25	(–)
left side	20	0	40	(–)
d rotation around sagittal axis perpendicular to clivus				
right side		0		0
left side		0		0
Quadrigeminal cistern				
1 *Body of cistern lat proj*	50		75	
a p displacement		p++		p+
kinking of quadrigeminal plate		++		+
rotation of inferior end *of quadrigeminal plate*		ip++		ip+
2 *Precentral fissure lat proj*	30		50	
a p displacement		p++		p++

Quadrigeminal cistern

Posterior displacement of the quadrigeminal cistern occurred in both groups of tumours but was as a rule more marked in the cases with tumours from the roof (Table 5) A kinking of the quadrigeminal plate was present in many cases in both groups and this also was more marked in the cases with tumours from the roof Anterior rotation of the inferior part *of the* quadrigeminal plate was not observed in any of the cases whereas posterior rotation was common in both groups being as a rule more marked in the cases with roof tumours

The precentral fissure was usually markedly displaced in the posterior direction in both groups of tumours

As has been pointed out previously (LINDGREN & DI CHIRO LINDQVIST 1980a) the appearance of the quadrigeminal cistern is intimately related to that of the aqueduct and the fourth ventricle Intraventricular tumours of the fourth ventricle cause dilatation of the ventricle (MOLLER) and as a rule also of the aqueduct This dilatation causes a posterior displacement of the quadrigeminal cistern and the precentral fissure and the inferior part of the quadrigeminal plate rotates posteriorly (Fig 7a b) In cases with marked dilatation of the aqueduct and the fourth ventricle an upward herniation of the anterior medullary velum below the quadrigeminal plate sometimes occurs (MÖLLER) In these cases the precentral fissure is either totally compressed (Fig 7c d) or displays extreme posterior displacement



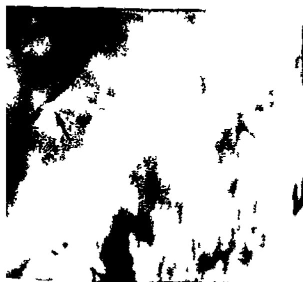
Fig 6 Tumour from the roof in the vicinity of the fastigium (position IIb) Encephalography lateral tomography in the supine position The anterior part of the third ventricle is markedly dilated with compression of the interpeduncular cistern (→) No definite superior displacement of the pons (↔) in spite of the supero-inferior compression of the interpeduncular cistern *Also the* chiasmatic cistern is compressed by the widened third ventricle



a



b



c



d

ig 7 a b) Intraventricular tumour from the floor (position b 1) a) Encephalography lateral tomography The inferior art of the quadrigeminal plate is somewhat rotated posteriorly →) The precentral fissure (↔) is moderately displaced pos riorly The superior cerebellar cistern (⊳→) is compressed and ıe distance between the precentral fissure and the superior erebellar cistern is decreased indicating a compression of ıe superior vermis b) Ventriculography lateral tomography loderate widening of the fourth ventricle and a slight widening of the aqueduct c d) Tumour from the floor (position V b 4) c) Encephalography lateral tomography Only slight filling of the quadrigeminal cistern or the precentral fissure in spite of good filling of the cisterna veli interpositi (→) and the pericallosal cistern (↔) d) Ventriculography lateral tomography Extreme widening of the aqueduct and the fourth ventricle The anterior medullary velum (→) herniated upwards below the quadrigeminal plate

Remaining cisterns

The crural cisterns were filled in approximately 40 per cent of the cases no specific distortions were noted

The chiasmatic cistern was filled in all cases with floor tumours and in 80 per cent in the other group As in cerebellar tumours (LINDQVIST 1980 a) the chiasmatic cistern was compressed in cases with supratentorial ventricular dilatation (Fig 6) The cistern was otherwise not significantly abnormal

The cistern of the lamina terminalis was demonstrated in approximately 50 per cent of the cases without specific features

The superior cerebellar cistern was demonstrated

Typical cisternal distortions produced by tumours from the roof and from the floor of the fourth ventricle

Lateral projection

Tumours from the roof	Tumours from the floor
Tonsillar herniation Exception: In a few cases the tumour extends out into the foramen of Magendie and the vallecula causing separation of the tonsils. In these cases the tumour pole instead of the tonsils may extend below the foramen magnum	*Tumour extension via the foramen of Magendie to the cisterna magna below the foramen magnum* Exception: In some cases the tumour does not grow out through the foramen of Magendie and in these cases tonsillar herniation may be present instead
Marked posterior and inferior displacement of the retrotonsillar spaces	Marked posterior displacement and moderate inferior displacement of the retrotonsillar spaces
Compression of the interhemispheric part of the cisterna magna against the occipital crest Exception: In cases with a tumour component in the cisterna magna this part of the cistern is widened instead	Compression of the interhemispheric part of the cisterna magna against the occipital crest
Anterior displacement of the foramen of Magendie	Posterior displacement of the foramen of Magendie
Compression of the premedullary part of the medullary cistern	Compression of the premedullary part of the medullary cistern
Moderate compression of the pontine cistern, sometimes more marked inferiorly than superiorly	Moderate compression of the pontine cistern, sometimes more marked inferiorly than superiorly
Marked supero-inferior compression of the interpeduncular cistern and slight superior displacement of the pons	Marked supero-inferior compression of the interpeduncular cistern and moderate superior displacement of the pons
Kinking and posterior displacement of the quadrigeminal plate with posterior rotation of the inferior part of the plate	Slight kinking and posterior displacement of the quadrigeminal plate with slight posterior rotation of the inferior part of the plate
Marked posterior displacement of the precentral fissure	Marked posterior displacement of the precentral fissure

Axial projection

Tumours from the roof	Tumours from the floor
Increased width of the inferior vermis	*Increased width of the inf… vermis*
Widening of the vallecula without lateral displacement Exception: In cases without tumour extension to the foramen of Magendie the width of the vallecula may be normal or reduced. Lateral displacement may occur in cases with asymmetric tumours	Widening of the vallecula without lateral displace… Exception: Lateral di… ment may occur in case… with asymmetric tumou…
Separation of the cerebello-medullary fissures	Separation of the cerebell… medullary fissures
Anterior compression with increased transverse diameter of the medulla oblongata	Anterior compression wi… creased transverse diame… of the medulla oblongata
Symmetric compression of the lateral recesses of the medullary cistern Exception: In cases of asymmetric tumour a slight lateral displacement as well as some anterior rotation of the medulla oblongata may occur on the tumour side	Symmetric compression … lateral recesses of the medullary cistern
Symmetric compression of the pontocerebellar cisterns and the same degree of compression medially as laterally Exception: In cases of asymmetric tumour the compression may be more marked on the tumour side	Symmetric compression of… pontocerebellar cistern usually more medially tha… laterally

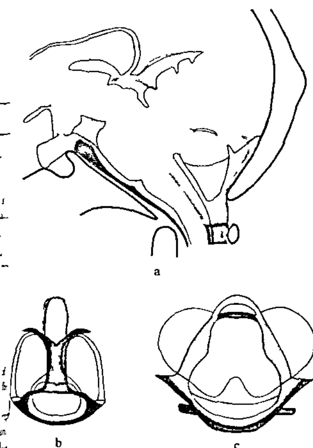


Fig 8 Drawings of some important cisternal deformities in tumours from the roof of the fourth ventricle a) Lateral view b) Axial view of the cisterns inferior to the fourth ventricle c) Axial view of the cisterns adjacent to the tentorial notch The normal appearance of the cisterns is indicated by means of continuous lines Cisternal structures possible to evaluate in tumour cases are indicated with shaded areas (cf LINDQVIST 1980a Fig 1)



Fig 9 Drawings of some important cisternal deformities in tumours from the floor of the fourth ventricle a) Lateral view b) Axial view of the cisterns inferior to the fourth ventricle c) Axial view of the cisterns adjacent to the tenorial notch (cf Fig 8)

in the lateral projection in approximately 30 per cent of the cases Its width varied In most cases where the cistern could be evaluated the superior vermis was compressed (Fig 7a) as with tumours of the anterior compartment of the posterior fossa

The pericallosal cisterns were demonstrated in the axial projection on one or both sides in approximately 20 per cent of the cases with tumours from the roof and in approximately 40 per cent in the other group *The wings of the ambient cistern* were filled in 20 per cent of the cases with roof tumours and in 75 per cent of those with floor tumours *The cisterna veli interpositi* was filled in approximately 10 per cent of both groups All these cisternal structures were often markedly dilated in cases with hydrocephalus normal or insignificantly dilated in cases without hydrocephalus

As in the case of the cerebellar tumours (LINDQVIST 1980a) no correlation was found in cases with unilateral filling between the side of the tumours and the filled side of these cisterns in the presence of a lateral tumour

Typical cisternal distortions associated with intraventricular tumours from the roof and from the floor respectively are listed on page 10 and illustrated schematically in Figs 8 and 9

The cisternal abnormalities in cases with tumours of the pontine angle and of the brain stem will be discussed in a forthcoming report (LINDQVIST 1980b) and the differences between cisternal abnormalities in various tumour sites will be discussed in that context

SUMMARY

A detailed analysis of the distortion of the subarachnoid cisterns produced by intraventricular tumours of the fourth ventricle was carried out on a clinical material of 30 patients examined with pneumography The cisternal distortions in cases with a tumour originating from the roof of the ventricle have been compared with those in tumours originating from the floor and the typical appearances for each group of tumours are recorded The results should be applicable when analysing cisterns examined not only with pneumography but also with other radiologic methods such as computer tomography and cisternography with positive contrast media

ACKNOWLEDGEMENTS

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OM THE DEPARTMENTS OF DIAGNOSTIC RADIOLOGY (DIRECTOR J GOTHLIN) AND NEUROLOGY (DIRECTOR J A AARLI) UNIVERSITY OF BERGEN MEDICAL SCHOOL N 5016 BERGEN NORWAY

ARACHNOIDAL DIVERTICULA AND CYSTLIKE DILATATIONS OF THE NERVE-ROOT SHEATHS IN LUMBAR MYELOGRAPHY

J L LARSEN D SMITH and G FOSSAN

The anatomy and the radiologic appearance of lumbosacral nerve roots and their sheaths have been described by numerous authors (for review see CAPESIUS & BABIN 1978) It is well known that the width of the root sheaths varies considerably and that they sometimes may appear as cystlike pouches They are not to be confused with epidural cysts nor with the perineurial cysts first described by TARLOV (1938) They must be regarded as unusually wide root pockets covering the emerging nerve root between the dural sac and the fusion of the arachnoid and the perineurium Such dilated root sheaths were reported by CAPESIUS & BABIN in an incidence of 5 to 10 per cent The present investigation was undertaken with the following intentions to establish the incidence of root sheath diverticula in a series of patients examined by lumbar myelography to estimate the possible significance with regard to clinical symptoms and signs and to establish a possible relationship with a wide dural sac (mega-cauda or mega sac)

Material and Methods

Lumbar myelography with 6 75 g metrizamide (Amipaque Nyegaard Norway) at a concentration of 250 mg I/ml was performed in 136 patients referred because of low back pain or sciatica The usual projections were used horizontal in right and left lateral positions prone and oblique decubitus a p in standing and lateral views in sitting position with flexion and extension of the spine were included Due to differing sizes of the patients and difficulties in obtaining films in exactly reproducible positions a system with proportionate measurements was chosen Based on a preliminary analysis of normal roots and sheaths the normal limit was defined as the root occupying at least half of the combined diameter of the root and the root sheath the measurement being performed at right angles to the direction of the root in the view demonstrating the largest diameter of the rooth sheath (Fig 1) Roots obviously affected by prolapse or osteochondrotic lesions with deformity caused by compression or edema should not be included however no case with such lesions affecting widened sheaths was found but as the filling of the root pockets was often scanty in the diseased roots the possibility of such lesions cannot be excluded

Results

Abnormally wide nerve root sheaths were found in 24 of the 136 patients The total number of wide sheaths was 49 Twelve of the patients had only one in the lumbosacral region and the highest number in one patient was 7 The most commonly affected root was the first sacral (Table 1)

It has been assumed that wide root pockets are more common in advanced age Grouping the present patients revealed no significant sex or age differences between patients with and without widened sheaths

The distribution of dilated sheaths according to relative size at proportionate measurements appears in Table 2

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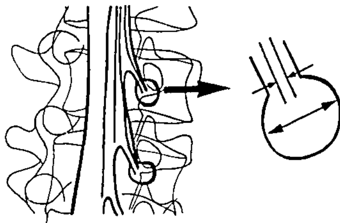


Fig 1 Method of measurement As the root has an even diameter along its distal course it is often conveniently measured a little proximal to a diverticulum

Table 1

Distribution of rooth sheath diverticula

Root affected	Right	Left
L1	1	2
L2	3	2
L3	3	1
L4	1	1
L5	1	1
S1	11	7
S2	6	5
S3	1	3
Total	27	22

Morphologically the widened sheaths or diverticula could be divided into three categories tubular with a more or less even diameter along the course (Fig 2a) saccular also known as drop like located at the distal end of the root sheath (Fig 2b) and uneven in appearance often as a combination of 1 and 2 (Fig 2c) Of the 49 dilated sheaths 12 belonged to the first category 24 to the second and 12 to the third one patient having a drop like widening at the proximal part of the root was not classified (Fig 3)

It has been assumed that root sheath dilatations occur more often when the dural sac is large so called mega cauda or properly mega sac Two methods of classification in this condition have been described In the first one described by KOMMINOTH et coll (1968) the transversal diameter of the dural sac is related to the interpeduncular distance at L5 a ratio of one or close to one being taken as representing mega sac (Fig 4) The other method was described by CHAOUAT et coll (1974) who proposed sagittal measurements and considered an antero posterior diameter of the sac of more than half that of the corresponding vertebral body to indicate mega sac (Fig 4) In the present series both methods were employed at the level of L5 (in a few of the patients supplemented at the L4 level when in doubt) Only measurements on films in the erect or sitting position were used in order to ensure good filling and distension of the sac One patient with paraplegia was therefore omitted and in two other patients only one of the methods could be used with reliability The results were affirmative for mega sac by the method of CHAOUAT et coll in 5 of 23 patients with wide root sheaths in 3 of these 5 also by the method of KOMMINOTH et coll with one questionable (index 37/42 mm) and one not measurable as the remainder

There was a tendency for patients with wide lumbar root sheaths also to have wide sheaths in the thoracic region The conus and lower thoracic region was often included but not as a strict routine Thus the concordance cannot be numerically assessed One female aged 69 in whom the spinal canal was filled by contrast medium from Th7 distally had diverticula on 14 of the 26 demonstrated root sheaths (Figs 2c 5)

All patients had a complete neurologic examination by an experienced neurologist or neurosurgeon In no case could symptoms or signs from the roots with wide sheaths or diverticula be demonstrated

Discussion

Incidence of diverticula A diverticulum is defined in the present series as a widening of the root sheath in which the subarachnoid space occupies more than

Table 2

Total transversal diameter of root and sheath

Ratio	$\frac{2}{1}$	$\frac{2\text{-}3}{1}$	$\frac{3}{1}$
No of diverticula	22	11	16



Fig 2a Fig 2b



Fig 2c Fig 3

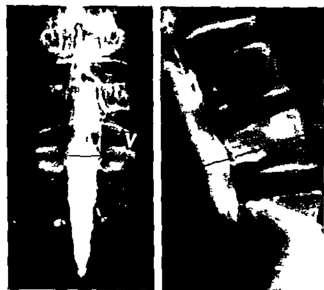


Fig 4

Fig 2 Tubular diverticulum on S1 root (→) The root sheath of S2 also appears wide although not classified as a diverticulum Prolapse of L3 disc b) Typical drop-like diverticulum (→) on right S root Narrow connection between the diverticulum and the caudal sac c) The left L5 and S1 roots (→) are encircled by a large uneven diverticulum Small diverticulum on L2 root (Same patient as in Fig 5)

Fig 3 Proximal dilatation of the root sheath of S2 (→)

Fig 4 Assessment of possible mega sac using a p (KOMMINOTH et coll) and lateral (CHAOUAT et coll) projection

50 per cent of the total transversal diameter of root and sheath together Using this definition 17 6 per cent of the 136 patients had diverticula in the lumbosacral region This figure is higher than those given in most radiologic anatomic or pathologic publications One reason for this may be the limit set towards normality Perusal of the literature has not revealed any precise criteria which is an obvious difficulty in comparing materials

Of pathologic reports reference will be made to two SMITH (1961) reported cystlike formations in 9 per cent of 100 consecutive autopsies They were

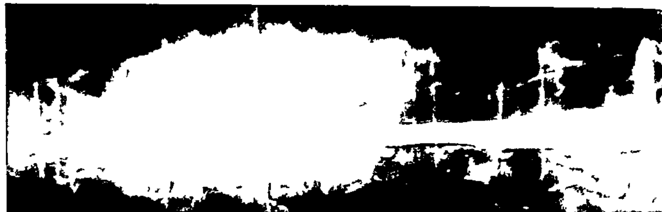


Fig 5 Same patient as in Fig 2c Several diverticula in the thoracic region (the patient with the largest number of diver ticula)

found at thoracic lumbar and sacral levels No further details as to location or frequency were given HOLT & YATES (1964) examining 120 speci mens of the cervical spine from elderly patients found cystic changes in 37 (30 8%) However some of these were stated to have been detected only at microscopy the frequency not given The number of widenings varied from 1 to 6 Totally 65 roots were affected giving an average of 1 8 per patient Considering the number of cervical roots in relation to that in the lumbosacral region this result is in accordance with the incidence in the present series

The lower figure of 5 to 10 per cent cystlike con ditions and dilatations of the lumbosacral nerve root sleeves reported by CAPESIUS & BABIN who did not state the usual cranial extension of contrast medium at myelography can be explained by the fact that the upper lumbar roots were not demonstrated in all their patients Both ARNELL (1948) and LINDBLOM (1948) stated that the root sheaths vary in length and width without further analysis SCHOBER (1963) in a material of 247 myelographies in different regions found 20 patients with cystic lesions 16 lumbosa crally and 4 cervically but none in the thoracic region From the illustrations it is evident that both oily and water soluble contrast media were em ployed As the root sheaths are not adequately demonstrated with the oily media a true incidence is not to be expected

Clinical significance In no case was any correla tion found between dilated meningeal sheaths and clinical symptoms or signs This is in accordance with previous experiences (SCHOBER CAPESIUS & BABIN STEWART & RED 1971) A diverticulum must be large enough to produce pressure upon the roots for symptoms to occur In case of a narrow communication with the main subarachnoid space the possibility exists that this may be closed and a true cyst be formed and possibly impinge upon the bony spinal canal the medulla and the nerve roots Hypothetically the same effect may be elicited by a valve mechanism at the entrance of the diverticu lum making possible entrance but not escape of spinal fluid

Relation to mega sac In 5 of 23 patients (2 the dural sac was found to be unusually large in relation to the bony canal KOMMINOTH et coll found an incidence of mega sac in 60 of 4 584 selected lumbosacral myelographies i e an in cidence of 1 3 per cent The positive correlation between mega sac and diverticula thus seems to be evident It is known that the wall of the diverticu lum in many cases is thin and atrophic (HOLT & YATES) Information as to whether the meningeal wall in mega sac is atrophic is not available but if such is the case the pulsatile force of the cerebro spinal fluid could explain the concordance of mega sac and diverticula

The hydrostatic pressure of the cerebrospinal fluid is assumed to play a role in the formation of the subarachnoid diverticula (STRULLY 1956 SMITH) HOLT & YATES found a definite increase in diver ticular size in caudal direction but this referred only to the cervical region SMITH too reported increas ing diverticular size in caudal direction without any further details as to frequency of location In the present series the S1 and S2 roots were most often affected these two locations carrying approximately 60 per cent of the diverticula For the rest the diver ticula were haphazardly distributed with no definite predominance in caudal direction This means that factors other than the hydrostatic pressure must

an important role these factors being predomi ntly present in the root sheaths of the first and cond sacral nerve If dilatation should occur on basis of a large root sleeve a greater tendency diverticula would be expected on the L5 roots these together with the first sacral harbour the gest sleeves Mechanical factors could also be olved as the lower lumbar and first sacral roots subject to the relatively largest movements in ation to the intervertebral foramina in flexion of spine (BREIG 1960) However the low incidence diverticula of L5 is then difficult to explain No nificant difference in age existed between patients h and without diverticula in the present series If hydrostatic pressure should be the major factor ponsible for meningeal dilatation increased fre ency in the older age groups is to be expected

SUMMARY

Diverticulum like widening of one or several nerve root aths was found in 24 of 136 patients examined by lum r myelography No clinical significance of the diverti la was demonstrated The roots most commonly af ted were the S1 and S2 roots carrying approximately per cent of the diverticula A system of classification cording to morphology and to size compared with the ot involved is proposed A relationship between mega c and arachnoidal diverticula is confirmed

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ANGIOGRAPHIC DETERMINATION OF CEREBRAL BLOOD FLOW

B M T LANTZ J M FOERSTER D P LINK and J W HOLCROFT

Currently no ideal technique for measuring cere ral blood flow in humans is available Such a tech que would be non invasive instantaneous and re atable (POSNER 1972) Furthermore the method ould measure regional as well as total blood flow to ie brain i e extracranial as well as intracranial ow The ideal technique would not involve radioac vity and not require hospitalization (CARR & FISH R 1970) At present several different techniques are mployed each of which has its advantages and dis dvantages limiting its properties as an ide il method f measuring cerebral blood flow Four major prin iples are utilized in this regard Fick principle itewart Hamilton principle (indicator dilution) ool transit time by extracranial counting and me hanical flow meters

By the Fick principle (KETY & SCHMIDT 1948) the rteriovenous difference of inhaled nitrous oxide is neasured over a period of 10 min from several ar terial and jugular venous blood samples The meth od requires arterail as well as venous catheteriza tion By the same principle isotope clearance meth od requires arterial as well as venous catheteriza 1969) and ¹ O (TER POGOSSIAN et coll 1970) These isotope clearance methods have the advantage of measuring regional blood flow and can be repeated several times However self absorption and scatter can lead to overlap of regions and carotid puncture is required The ^{15}O method has the advantage of simultaneously measuring regional cerebral flow and central nervous system metabolism but the emission is difficult to collimate the isotope has a short half life and requires a cyclo tron

Conventional indicator dilution methods using non diffusible isotopes have been used for a long time The technique is however cumbersome and difficult to use Bolus injection of hydrogen gas into each internal carotid artery has been described by MEYER & SHINOHARA (1970) By this method it has become possible to estimate hemispheric blood flow and to compare one hemisphere with the other utilizing dissolved hydrogen as the indicator The method requires bilateral catheterization of the carotid arteries and jugular veins

The brain transit time of intravenously injected isotopes has been used to estimate the cerebral blood flow The method is easy to perform re peatable and atraumatic to the patient However it does not measure the cerebral blood flow but rather the transit time across the brain (OLDENDORF 1970)

Of the mechanical methods of measuring cerebral blood flow thermal velocity and thermal dilution techniques have found little use in humans The Doppler principle is non invasive and instantaneous and will give continuous measurements of velocity It provides only semiquantitative measurements of relative changes in blood velocity and is quite sensi tive to the patient s movement and to the position of the probe On the other hand electromagnetic flow meters are quite accurate and give a continuous measure of the blood flow This technique requires surgical exposure of the carotid arteries and thus is not fit for use in normal clinical examinations

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A new method of determining the cerebral blood flow is now presented which can easily be used in conjunction with routine cerebral angiography A catheter is positioned in the carotid artery fluoro scopically Injected contrast medium then is utilized as dilution indicator for estimating the flow in each artery as a fraction of the cardiac output No sampling catheters are required Besides the usefulness of the method as a basic physiologic and pathophysiologic tool clinical situations appear where such measurements can be of great importance JENNETT et coll (1966) demonstrated that a flow decrease of 25 per cent or more in the carotid flow would be extremely valuable in evaluating patients with intra cerebral aneurysms requiring carotid artery ligation Such a method might also be useful before carotid endarterectomy in the diagnosis of cerebral ischemia in determining the prognosis in a comatose patient and in treatment of stroke and brain injury (HARPER 1971)

The present method measures relative flow utilizing the videodensitometric technique described by LANTZ (1974 1975) The method has recently been applied for measurements of renal blood flow (LINK et coll 1979) and splanchnic blood flow (LANTZ et coll 1980) The blood flow of each cerebral vessel can be measured as a fraction of the cardiac output

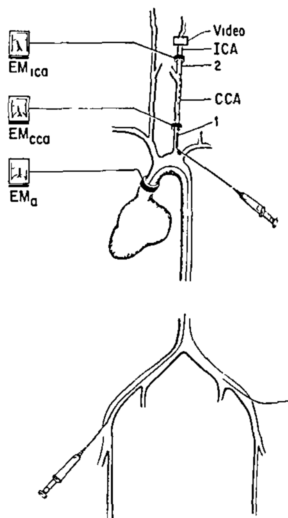


Fig 1 Diagram of the canine model Flow in the ascending (EM) the common carotid artery (EM) and the internal tid artery (EM_{ic}) was continuously monitored utilizing el magnetic flow probes One angiographic catheter was p nently positioned in the ascending aorta and another one placed with the tip in the common carotid artery (posit and in the internal carotid artery (position 2) alternatel videodensitometric recordings were performed at the sam over a branch of the internal carotid artery (Video) Blood sure (BP) was recorded via an iliac cannula and pressure t ducer

Videodensitometric estimate of relative flow

The videodensitometer is an electronic instrument capable of measuring density changes in a selective region of the television image It is characterized by high sensitivity and a rapid dynamic response Density changes in the fluoroscopic television image caused by injected contrast medium can be quantified and recorded as a dilution curve The integrated area under the densitometric curve reflects the blood flow at the site of injection upstream and not at the site of recording The densitometric area A is directly proportional to the amount of injected contrast medium M and inversely proportional to the blood flow Q at the site of injection according to (LANTZ 1975)

$$A=\frac{M}{Q}k$$

thus

$$Q=\frac{M}{A}k$$

where k is a proportionality constant affected by radiation intensity and the gains of the televi chain and recording equipment By injecting c trast medium at two sites of the circulatory sy and by recording the densitometric dilution cu downstream at a fixed site of the artery it is poss to compare the flows at the sites of injection

$$\frac{Q_1}{Q_2}=\frac{M_1 A_2}{M_2 A_1}$$

where Q_1 and Q_2 are the flows at the sites of in tion M_1 and M_2 are the amounts of contrast med

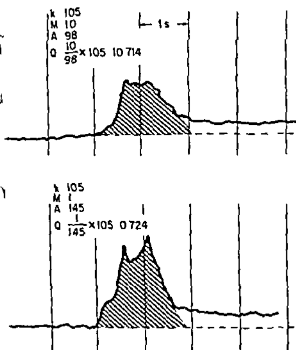


Fig 2 Videodensitometric flow calculation in the common carotid artery as a fraction of the cardiac output Top curve represents the recording obtained over the internal carotid artery after contrast medium injection in the ascending aorta Bottom curve represents the videodensitometric recording at the same site after selective injection in the common carotid artery The flow Q is calculated from M (amount of contrast medium injected) A integrated densitometric area shaded) and k (calibration factor for radiation intensity) according to $Q = \frac{M}{A}$ k The flow in common carotid artery as a fraction of the cardiac output is $\frac{0\ 7\ 4}{10\ 714}$ = 7 per cent

injected at the two sites and A_1 and A_2 are the integrated densitometric areas measured from the densitometric dilution curves If for example the flow in the right common carotid artery is to be estimated as a fraction of the cardiac output two contrast injections will be made one in the ascending aorta where total cardiac output passes and one in the proximal part of the right common carotid artery The two dilution curves recorded over the right internal carotid artery will then reflect the blood flow in these areas

Materials and Methods

The blood flow in the common carotid artery and the internal carotid artery was determined as a fraction of the cardiac output in an in vivo canine model (Fig 1) Estimates obtained by the videodensitometric method were compared to the corresponding electromagnetic flow readings in 2 mongrel dogs weighing 25 and 32 kg respectively The dogs were anesthesized with 30 mg/kg of sodium pentobarbital and were ventilated with a Harvard pump on room air The cardiac output was continuously recorded by a circumferential electromagnetic flow probe around the ascending aorta 2 to 4 cm above the aortic valve A similar electromagnetic probe was attached to the proximal part of the left common carotid artery and another to the proximal part of the left internal carotid artery The probes were connected to electromagnetic flow meters (Statham SP 2200) The systemic blood pressure was recorded via a cannula in the left common iliac artery attached to a Statham P23DB pressure transducer

The videodensitometric flow in the left common carotid artery was calculated as a fraction of the cardiac output from two dilution curves derived from a bolus injection of sodium iothalamate (Conray 400) through a 7 French pigtail catheter with its tip in the ascending aorta and from a second bolus injection through a 6 French catheter with its tip in the proximal part of the left common carotid artery With respiration suspended and the dog in a fixed position 10 ml contrast medium was injected in the ascending aorta followed by a 1 ml injection into the common carotid artery When the blood flow in the internal carotid artery was determined as a fraction of the cardiac output the selective 6 French catheter was advanced to the internal carotid artery for a 1 ml contrast injection The selective injections were performed manually and the aortic injections by a Cordis II pressure injector Nine series of injections were performed each consisting of one aortic injection followed by one or more selective injections The video image was recorded on video cassette with the image intensifier in a fixed position covering a main branch of the left internal carotid artery Before each recording performed in constant fluoroscopy with fixed kV and mA a 10 mm aluminum filter was used for calibration of the radiation intensity The videodensitometric dilution curves were displayed at a later time by replaying the cassette A videodensitometer with an output voltage proportional to the logarithm of the incident radiation was used (T Strand Siemens Elema Sweden) Integration of the videodensitometric mass time curves was performed by planimetry

The video image was recorded on a Sony Umatic video cassette recorder The data from the electromagnetic probes along with the arterial pressure were recorded on an Electronics for Medicine DR 8 photographic recorder and synchronized with the

Table 1

Twenty nine measurements of the flow in the common carotid artery as a fraction of the cardiac output were recorded by the magnetic and videodensitometric methods Each of the 7 series represents one contrast injection in the ascending aorta followed one or more subsequent selective injections in the common carotid artery at different time intervals The difference in percent between the videodensitometric and electromagnetic method is displayed in column E

Series	n	Time (min)	A Electromagnetic flow (ml/min)	B	C Electromagnetic ratio (per cent common carotid flow)	D Videodensitometric ratio (per cent common carotid flow)	E Difference (per cent) D–C
			Cardiac output	Common carotid artery			
1		0	4 090				
	1	9		261	6 4	6 3	−0 1
	2	11		261	6 4	5 6	−0 8
	3	15		279	6 8	5 4	−1 4
	4	16		264	6 5	5 3	−1 2
	5	18		245	6 0	5 1	−0 9
2		0	3 240				
	6	2		256	7 9	5 1	−2 8
	7	3		256	7 9	5 6	−2 3
	8	4		261	8 0	6 6	−1 4
3		0	3 350				
	9	4		279	8 3	8 9	0 6
	10	5		290	8 7	7 3	−1 4
	11	6		292	8 7	6 7	−2 0
4		0	4 100				
	12	14		299	7 3	5 2	−2 1
	13	18		299	7 3	5 6	−1 7
	14	20		327	8 0	7 6	−0 4
	15	23		322	7 9	7 4	−0 5
	16	25		322	7 9	8 8	0 9
5		0	4 150				
	17	2		346	8 3	7 5	−0 8
	18	5		307	7 4	8 2	0 8
	19	7		299	7 2	6 8	−0 4
	20	9		315	7 6	6 8	−0 8
	21	11		315	7 6	7 6	0 0
6		0	3 400				
	22	15		88	2 6	2 5	−0 1
	23	18		109	3 2	3 5	0 3
	24	19		81	2 4	2 6	0 2
	25	20		85	2 5	2 3	−0 2
7		0	3 400				
	26	2		154	4 5	3 8	−0 7
	27	4		158	4 6	3 6	−1 0
	28	6		158	4 6	3 5	−1 1
	29	11		153	4 5	3 2	−1 3
					x=7 53**	x=6 64	x̄=−0 78
					S D =0 76	S D =1 21	S D = 0 92

Partial obstruction (manual) of the common carotid artery
Series 6 and 7 excluded

Table 2

...ven measurements of the internal carotid flow as a fraction of the cardiac output were recorded by electromagnetic and video-densitometric methods. Each of the 2 series represents one contrast injection in the ascending aorta followed by several subsequent ...ctive injections in the internal carotid artery at different time intervals. The difference in percentage between the videodensitometric and electromagnetic method is displayed in column E

...ries	n	Time (min)	A Electromagnetic flow (ml/min) Cardiac output	B Electromagnetic flow (ml/min) Internal carotid artery	C Electromagnetic ratio (per cent internal carotid flow)	D Videodensitometric ratio (per cent internal carotid flow)	E Difference (per cent) D−C
		0	3 250				
	30	3		216	6.6	5.9	−0.7
	31	5		216	6.6	5.8	0.8
	32	6		213	6.6	6.3	0.3
	33	7		221	6.8	6.0	0.8
	34	9		208	6.4	6.3	−0.1
	35	11		198	6.1	6.6	0.5
		0	2 750				
	36	10		183	6.7	5.5	−1.2
	37	13		216	7.9	5.5	−2.4
	38	14		193	7.0	4.1	−2.9
	39	15		188	6.8	5.1	−1.7
	40	16		188	6.8	4.5	−2.3
					x=6.75	x=5.60	x=−1.15
					S.D.=0.45	S.D.=0.77	S.D.= 1.06

...ideo tape recording of the contrast medium injec...ons. A constant potential generator (C.G.R. 1215 ...1200 mA) was used. The fluoroscopic equipment included a cesium iodide image intensifier with a plumbicon television camera (C arm C.G.R. triple field image intensifier). A 10 cm (4") intensifier input was used in all experiments.

Results

Nine series of measurements were obtained with 40 paired ratios of cerebral blood flow and cardiac output by the videodensitometric and electromagnetic methods. The videodensitometric recordings from a typical data pair are illustrated in Fig. 2. Extrapolation of the videodensitometric curves was required because of background accumulation of contrast medium which prevented the curve from returning to baseline. This is a generally accepted technique in other dilution methods.

Common carotid artery flow. Twenty nine paired data comparing the common carotid flow and the cardiac output are displayed in Table 1. In series 6 and 7 partial obstruction of the common carotid artery was manually performed to decrease the flow. The mean common carotid flow ratio (series 1–5) was 7.53 per cent (SD=0.76) calculated by the electromagnetic method and 6.64 per cent (SD=1.21) by the videodensitometric method respectively. The mean difference between the methods was −0.78 per cent (SD=0.92) for all 7 series.

Internal carotid artery flow. Two series containing 11 paired ratios of the internal carotid artery flow are displayed in Table 2. The mean flow as a fraction of the cardiac output was 6.75 per cent (SD=0.45) calculated by the electromagnetic method and 5.60 per cent (SD=0.77) by the videodensitometric method. Thus the mean difference was −1.15 per cent (SD=1.06).

Comparison of the electromagnetic and videodensitometric methods. The cerebral blood flow in absolute units (ml/min) was calculated in each of the 40 experiments from the videodensitometric ratio and the electromagnetic readings of the cardiac output according to

$$\frac{Q_C}{Q_A} \times \text{(electromagnetic cardiac output)} = \text{cerebral blood flow in ml/min}$$

where Q_C and Q_A are the videodensitometric flow in the cerebral artery and aorta respectively and

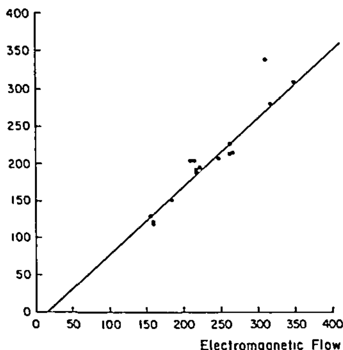


Fig 3 Correlation between simultaneously determined videodensitometric and electromagnetic blood flow (ml/min) for 40 measurements in cerebral arteries (r=0 91) The solid line is a least squares regression line

$\frac{Q_C}{Q_A}$ is the videodensitometric cerebral flow ratio

The cerebral flow in absolute units recorded by the videodensitometric and electromagnetic methods (Fig 3) displayed a good correlation (r=0 91)

Discussion

Present data indicate that about 17 per cent of the cardiac output in the resting state is devoted to the cerebral circulation (REINMUTH et coll 1965) In the present experiments the unilateral common carotid artery flow was estimated to 6 6 per cent by the videodensitometric method Taking into account both common carotid arteries and both vertebral arteries the figure seems to be within a reasonable range However the aim was not to estimate the cerebral flow in a canine model but to compare the new videodensitometric method with a given standard the electromagnetic method In the individual experiments the methods correlated well (r=0 91) Review of the data in Tables 1 and 2 shows that the videodensitometric values were significantly lower than the electromagnetic values A similar difference between the methods was previously noticed regarding the renal blood flow (LINK et coll) The difference may reflect an error in extrapolation of the dilution curve and the corresponding integr of the videodensitometric areas It could ... sent a consistent error in delivering the ... amount of contrast medium through the ... The accurate delivery of the desired amount ... trast medium depends on a completely filled ... theter Before each injection the catheter was f... with contrast medium A small washout at the ... of the catheter could occur between the time of ... theter filling and the injection A deficit from ... washout could represent a significant fraction of ... 1 ml injection into the cerebral artery Recircul... of contrast medium from veins and other bra... superimposed on the videodensitometric ... may be another cause of error However if ... vessels are included in the window the video ... can be replayed and the window location chang... a more appropriate position The effect of over... veins can also be avoided by a short arterial ... jection such that the arterial videodensitom... curve ends before venous recirculation begins

Incomplete mixing of contrast medium and bl... including layering might also be a source of e... The ascending aortic injection of contrast med... through the multi side hole pigtail catheter sh... give accurate mixing of blood and medium With ... selective injection it is anticipated that incom... mixing occurs However it has been shown (L... et coll) that perfect mixing does not seem to b... great importance as the videodensitometric ... measures total contrast mass over an arterial c... section rather than local concentrations of cont... medium within the vessel The injection rate sho... always be less than half of the arterial flow rate ... preferably not more than a fourth of the flow in ... ascending aorta and the cerebral artery In ... present experiments 1 ml of contrast medium ... injected over a period of not less than two seco... (30 ml/min) in a flow which was usually 200 ml/... or greater

In a clinical situation only one catheter with ... 4 side holes close to the tip will be used After ... jection in the ascending aorta the catheter will ... placed selectively into each main cerebral ar... After injection into the aorta it would be advis... to wait at least 5 to 10 min before the selective ... jection to avoid contrast effects upon the general ... culation Although no substantial change of th... ce... bral flow after ascending aortic injections was ... served the issue has been disputed vigorously in ... literature (TAVERAS & WOOD 1976) The effects

contrast medium after selective injection into the cerebral arteries can be neglected as they occur after the densitometric curves have been obtained over a main cerebral artery However when repeating the selective injections the same rule of thumb should be applied i e a time delay of at least 5 min The effect of contrast medium on the cerebral circulation depends upon the chemical constituents of the compound In the present experiments Conray 400 was used which is not approved for cerebral angiography in humans Using a very low dose (1 ml) no complications occurred in the dogs despite the considerable accumulated dose over the entire experimental period

It may thus be concluded that the videodensitometric method can be used as a simple clinical tool to evaluate the blood flow in the main cerebral arteries as a fraction of the cardiac output It is especially convenient to perform in conjunction with routine clinical cerebral angiography as selective catheterization is a normal part of the radiologic procedure The flow determination can be done in the interim between film series when the radiologist is waiting for the films to be processed The measurements can be made in any angiographic suite with the aid of a densitometer and video cassette recorder

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SUMMARY

Determination of blood flow in the cerebral arteries as a fraction of the cardiac output was performed by the videodensitometric method and compared to electromagnetic flow readings in dogs The method proved to be highly accurate in vivo confirming previous experiments in vitro It is simple to perform during routine cerebral angiography and may produce significant physiologic data not readily available by other means

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VIDEODENSITOMETRY FOR MEASURING BLOOD VESSEL DIAMETER

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Determining the intensity of blood flow with the aid of videodensitometry by measuring the flow rate of a contrast medium introduced into the vessels is a well known method which is now made suitable for clinical application in this department Knowledge of the cross sectional area of the blood vessel is needed for calculating the intensity of flow by this method If the cross section of the vessel may be assumed to be round the required area can be found by making a single measurement of the internal diameter However the accuracy with which the measurement is made has to meet high demands since the square of the diameter value is involved in the flow calculation (LANTZ 1975)

Various intravascular sensors specially designed for determining the diameter of blood vessels have been described in the literature One of them is based on the principle of electric impedance and measures the mean cross sectional area in the vessel (CONSTANTINESCO & MERLE 1977) while another operates on the electromagnetic induction principle (KOLIN & MACALPIN 1977)

The objection to these sensors is that they are invasive and as such expose the patient to extra stress This objection is not so strong in the case of another category of methods for measuring diameter with linear dimensions being measured on fluoroscopic images of blood vessels filled with contrast medium These methods require only the routine insertion of a conventional catheter into the vessel for injecting a contrast medium They are all the more attractive since they combine well with the determination of blood flow rates by videodensitometry after all a catheter is already located in the proper place

Moreover the fluoroscopic images made for measuring the blood flow rate can also be used for measuring the diameter so that the quantity of contrast medium can be restricted With the aid of simple instruments for measuring length linear measurements on the fluoroscopic images can be performed directly on a TV monitor screen (RUTISHAUSER 1969) on a photograph of the image or on cinefluorographic films (HELLSTEN & PETTERSSON 1977) These methods do not however yield the degree of accuracy which is required

A higher degree of accuracy can be obtained by TV fluoroscopy with which dimensions can be measured electronically from the video signal (videometry) The diameter of the contrast filled blood vessels can then be determined videodensitometrically employing a technique for measuring the pulse width in the horizontal TV lines

On the basis of a single horizontal TV line this method of measuring the video diameter was used by SILVERMAN (1971) GARDNER & WARNER (1967) described a system employing a special purpose diameter computer for measuring the pulse width in TV lines an external general purpose digital computer being used for averaging the measured pulse width obtained from several lines

The present report also describes a system for diameter measurement which is based on the application of videometry on fluoroscopic images

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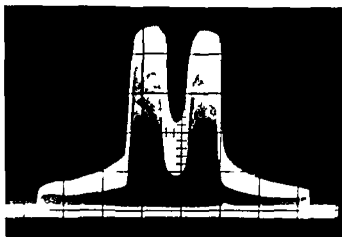


Fig 1 Photograph of a raw video signal The densitometric pulse obtained from a single tube filled with contrast medium

produced after injection of contrast medium into a blood vessel Use is made of a special video diameter computer instrumented with analog and digital elements This computer has the following special features

The densitometric pulse width in a TV line is measured on line with a half-depth width computing technique

the mean measured pulse width is established from several TV lines as an internal operation and

the optimum moment for diameter determination is found automatically

In vitro experiments were carried out on a transparent plastic phantom fitted with cylindric channels and on plastic tubes of known diameter and set water flow to test the quality of this method of measuring diameter

As a control of the practicability of the metho[illegible] vivo trials were performed in the abdomin[illegible] of an experimental animal (dog) The values fo[illegible] were compared with the results obtained w[illegible] intra arterial diameter sensor (VAN DER SCHEE BAKKER 1978)

Materials and Methods

The video diameter computer (VDC) A [illegible] of figures are given to illustrate the operation of th[illegible] computer In Fig 1 an oscilloscopic image disp[illegible] ing the video signal (5 μs/div 0 2 V/div) is ill[illegible]*trated*

All TV lines in an image are superimposed on th[illegible] oscilloscopic image The photograph was made a[illegible] the moment contrast medium was present in a pla[illegible]tic tube As the contrast medium passes a mome[illegible]tary dip appears in the video signal (the artery of the tube is made darker by the contrast medium) the width at half the depth of the dip being a y[illegible] stick for the diameter

The width at half the depth of the dip was chosen to ensure minimum disturbance from the noise contained in the video signal A visible window in which the location and dimensions can be set is introduced into the video image with the window generator (Fig 2) The window is adjusted so that it encom[illegible]

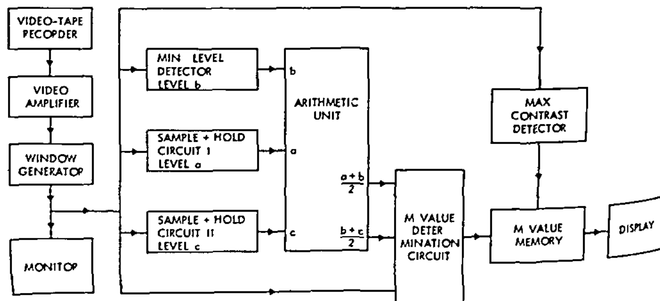


Fig 2 Block diagram of the video diameter computer (VDC)



; 3 Photograph of a TV monitor screen on which are displayed aorta of a dog a rectangular electronic window and the ected vessel wall during injection of contrast medium

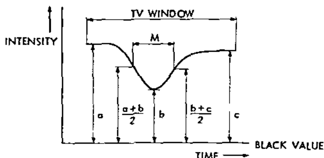


Fig 4 Diagram showing one TV line with the densitometric diameter pulse

sses the diameter of the artery or tube to be meas ed (Fig 3) The window generator allows only e video signal contained within the window to ss through to the measuring circuits

Fig 4 is a diagram showing the video signal of e TV line within the window during the presence contrast medium The time axis is electronically vided into intervals of 30 ns At the instant of the rst window edge appearing before the start of the ip in the video signal sample and hold circuit I easures and holds the voltage of the video signal value a in Fig 4) Next the minimum voltage of the ip is detected and held by the minimum level detec or (value b in Fig 4) Then at the instant at which he last window edge appears when the dip has gone rom the video signal sample and hold circuit II neasures and holds the voltage of the video signal value c in Fig 4) From these three values the arith metic unit (Fig 2) determines and holds the two threshold values (a+b)/2 and (b+c)/2 All these operations are completed before the next TV line begins

When the next TV line appears there is a pause until the video signal enclosed by the window has dropped below the stored threshold value (a+b)/2 (as determined in the preceding TV line) From that moment on the number of 30 ns intervals is counted by an electronic counter in the M value determina tion circuit Counting stops when the video signal enclosed by the window exceeds the threshold value (b+c)/2 stored in the preceding TV line

When the value of the video signal drops below or rises above the threshold this is indicated by a lumi nous spot in the video image so that the detected blood vessel wall is visible in the window (Fig 3)

For each frame all the lines lying within the set window are processed in this way In the M value determination circuit the sum of the 30 ns intervals is found and divided by the number of lines the width of which has been determined at the half depth of the dip This results in a value M (the VDC value)

During the passage of the contrast medium an appropriate detector determines the moment of maximum contrast at which the value M is stored in a memory The VDC value M may be read off from a three-digit display

Measuring systems All the experiments were made with standard equipment (Pandoros Optimatic Roentgen generator Siemens Bi 150/30/50 tube Siemens Sirecon Duplex 25/17 HN image inten sifier Siemens TV chain with Plumbicon Koordi nat Kombi diagnostic table Siemens Elema)

The fluoroscopic images were recorded with a video tape recorder (IVC 801 psm) The contrast medium (Isopaque 440 Nyegaard & Co) was in jected with a flow controlled angiographic injector (Medrad Mark III)

Photofluorography was performed with the aid of pulsed TV technique using a constant tube poten tial of 68 kV and an average tube current of 5 mA The focal spot was 0 6 mm The electron-optic en largement of the image intensifier was 170 mm The focus–input screen distance was constant at 95 cm The radiation beam was collimated down to a width of about 5 cm measured in the object plane to re duce scattered radiation For each measurement the tube current was adjusted to give a uniform level of luminance on the output screen of the image inten sifier for each experiment The optimum white level in the video signal was adjusted with the aid of the iris diaphragm in the TV camera Care was taken to ensure that the axes of the cylindric channels of the phantom the tubes and of the aorta were always pro jected perpendicularly to the lines in the TV image



Fig 5 Fluorographic image Intra arterial diameter sensor in situ in the aorta of a dog

Static test A transparent plastic block (Perspex) was used (approx 20 cm × 6 cm × 2 cm) into which eight cylindric channels (diameters 1 02 2 03 4 01 6 03 8 02 10 03 12 04 and 14 02 mm) had been drilled The axes of the channels were arranged parallel in one plane After the channels had been filled with contrast medium the block was put into a tray filled with water and placed on the coordinate table The columns of contrast medium were brought into the centre of the image one after the other by sliding the tabletop One series of exposures of the columns of contrast medium was made with the block lying on the bottom of the tray and with 10 cm of water above it The distance between the focal spot of the tube and the axis of a channel in the block was always 51 cm A second series of exposures was made with the block raised by 10 cm i e with 10 cm of water below it Both series were repeated with a 50 per cent water-diluted solution of contrast medium in the channels

Dynamic test In this test measurements were made with lengths of tubing of a flexible silicone plastic (Silastic Dow Corning) The internal diameters were 1 39±0 04 2 83±0 06 4 80±0 0[illegible] 6 45±0 05 7 9±0 2 9 6±0 1 and 15 4±0 3 [illegible] The wide spread in some of these values is due to the fact that the tubing used was found to be not exactly round One after the other the lengths of tubing were laid on the bottom of a water filled tray which was placed on the coordinate table Each in turn was brought into a recirculation system and flushed through with a constant flow of water (adjustable and readable) from a thermostatically controlled (37 C) reservoir The depth of water in the tray was 12 cm The distance between the focal spot of the tube and the axis of each length of tubing was 51 cm A straight 7 French multi side hole closed-end catheter (Cook) was introduced into each length of tubing at the upstream end and pushed forward until its tip appeared in the image Contrast medium was injected via this catheter

Television images of the formation and movement of the resulting contrast boluses in the lengths of tubing were recorded on video tape Injections were made into each length of tubing at three set values of the water flow velocity of v=10 20 and 40 cm/s Per velocity contrast medium was injected in quantities of q=1 3 and 6 ml the injection flow rate always being 17 ml/s No injections of the maximum quantity of 6 ml were made into the four narrowest gauge tubes to avoid exceeding the 500 psi pressure limit set in the injector The injections were repeated five times per setting

In vivo experiment A dog weighing 20 kg was used for the in vivo experiments The animal was kept without food for 12 hours before the examination given a general anaesthesia with Pentothal (thiopental) and then connected to a respiration unit Next catheterization was performed in accordance with usual angiographic practice

A 7 French pigtail catheter (Cook) was introduced into the right carotid artery and pushed through to the aorta until about 2 cm upstream of the bifurcation of the renal artery The tip of the catheter and the abdominal part of the aorta located downstream of it (about 10 cm in length) were brought into the image Upon injection of contrast medium photofluorography of the resulting contrast boluses in movement was performed Altogether 10 injections were made of 3 ml contrast medium each and at an injection flow rate of 17 ml/s The interval between

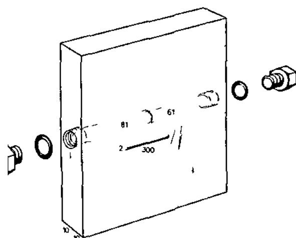


Fig 6

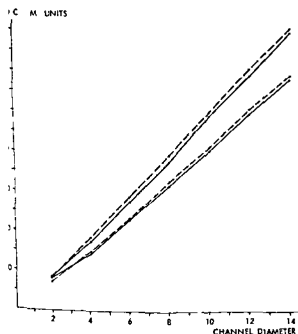


Fig 7

ig 6 Transparent view of the calibration block (dimensions in im)

ig 7 Results of static tests Relative diameters (in mm) deter ined by videodensitometry plotted against the internal diame ers of cylindric channels in a perspex block filled with contrast edium (100% — 50%) and for two distances from focal spot f tube to centre line of the channels (upper curves 51 cm lower urves 61 cm)

njections was at least 5 min This had been found experimentally to be long enough for disturbing pharmacologic reactions of the injected contrast medium to subside before the following injection

After the fifth injection the diameter measure ments were controlled with the aid of the intra arterial diameter sensor with resilient feelers (VAN DER SCHEE & DE BAKKER) Previously this sensor had been calibrated in the linear measuring range from 6 5 to 8 5 mm with an accuracy of ±0 5 per cent of the measured value

The sensor was inserted into the femoral artery and pushed through to the visible section of the abdominal aorta (Fig 5) During these measure ments the contrast medium catheter was tempora rily slightly withdrawn to make room for the dia meter sensor Under fluoroscopic control the feelers were positioned in five locations in the aorta (cor responding to the positions of vertebrae L2/L3 L3/L4 L4 L4/L5 and L5 respectively) At each location the diameter was measured with the sensor

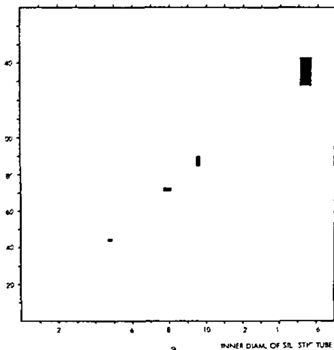
After completion of the last injection a calibra tion procedure was started in order to determine the absolute diameter values First the scale of enlarge ment of the aorta was established For this purpose the diameter sensor was removed and a special wire guide put in its place One end of the wire guide was built up of sections of metal alternating with sections of polyethylene each section was 20 0 mm long Photofluorography was performed on the end of the wire guide in the abdominal part of the aorta

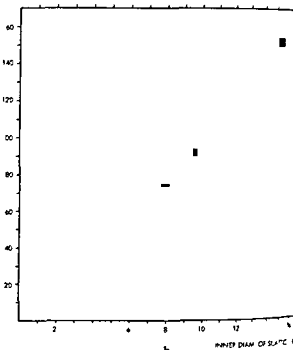
After the animal experiment was concluded the calibration procedure continued with the aid of a specially made transparent plastic calibration block (Fig 6) The block contained two calibration ducts of known diameter (6 1 mm and 8 1 mm respec tively) filled with contrast medium as well as a piece of copper wire of known length (30 0 mm) After the block had been placed in a water filled tray the latter was positioned on the coordinate table the water level in the tray was 12 cm The calibration ducts were positioned in the horizontal plane esti mated to have been previously occupied by the ab dominal aorta of the experimental animal

Experiments were made of the block with the axes of the calibration ducts and the copper wire lying in the same horizontal plane The ducts in the calibra tion block were filled with undiluted contrast me dium corresponding to the state in the aorta of the experimental animal immediately after injection of the contrast medium

Results

The tapes of the video recordings were played back on the recorder connected to the video dia meter computer Before playback the window deter mining the diameter measurement site was projected onto a previously selected position in the TV image The height of the window was set at 14 TV lines while the width was adjusted for each measurement





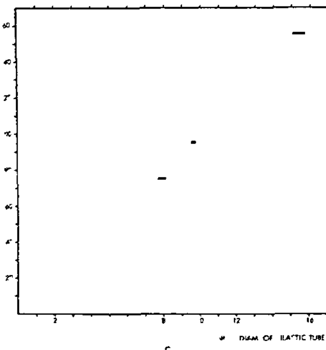


Fig 8 Results of dynamic tests Relative diameters determ by videodensitometry plotted against the internal diameters mm) of silastic tubes for injections of a) 1 b) 3 or c) 6 ml con medium into water passing through the tubes in a steady fl cm/s) The error is represented by a rectangle (the mean repeated injections) the height is twice the standard de the width is the uncertainty interval of the true diameter of a

Static test The window was positioned in the centre of the TV image on the image of the column of contrast medium During playback (lasting about 4 min) 15 consecutive measurements of the column width were made with the VDC thus producing a group of 15 VDC values per test As a rule the maximum spread per group was ± one VDC unit The standard deviation in the group of the second narrowest column (diameter 2 03 mm) was greater viz 4 units As a result of insufficient contrast reliable measurements could be made from t images of the narrowest column (diameter 1 02 m

The results of the static test are plotted in Fig For the sake of clarity the mean values for ea of the four series are joined by straight connect line segments in the graph The mean VDC val are a function of the concentration of the contr medium in the channels an inversely proportion

Table 1

ults of dynamic tests Mean and standard deviations (n=5) he relative diameters of silastic tubes determined by videositometry with a steady flow of water trough the tubes Three ml of contrast medium were injected

er meter ube mm)	Mean water flow velocity					
	10 cm/s		20 cm/s		40 cm/s	
	M units	SD	M units	SD	M units	SD
83	?5 6	0 5	25 4	1 1	25 6	0 5
80	45 4	0 5	45 4	0 5	45 6	0 5
45	61 6	0.5	6_2	0.5	61 4	0 7
9	73 7	0 5	74 1	0 5	7_9	0.5
6	90 0	0 9	9? 3	1 9	9? 7	0.5
4	15_0	3 0	151 0	2 0	15_0	4 0

nction of the focal spot distance and a linear function of the diameter of the channel—diameters over mm

Dynamic test The window was moved into the ntre of the TV-screen and placed over the image the Silastic tube the true distance from the visible p of the catheter was about 5 cm During playback f the dynamic tests the instant of diameter measrement during passage of the bolus of contrast edium was automatically determined by the VDC ne VDC value was obtained per test The contrast f the images of the boluses in the narrowest tube diameter 1 39 mm) was found to be insufficient for btaining useful measuring results VDC values ased on five repeated experiments each (those arried out under identical circumstances) were ombined and their mean values and standard deviaions were determined

The results of the dynamic tests are plotted in Fig 4 for the three quantities of contrast medium used (q=1 3 and 6 ml) and one water flow velocity (v=20 cm/s) The graph shows the trend of the average of the measured VDC values declining and of the spread increasing as the amount of contrast medium employed decreases This trend can be explained by the increasing chance of dilution of the contrast medium and incomplete formation of bolus under the circumstances referred to The static test results indicate that dilution of contrast medium entails declining VDC values Incomplete formation of bolus leads to inhomogeneous distribution of contrast medium over the cross section of the tube which in turn affects the proper functioning of the VDC

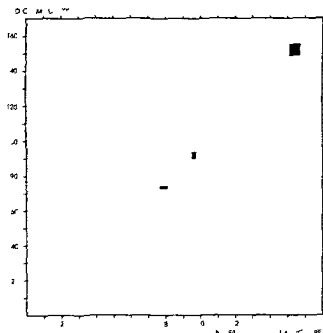


Fig 9 Results of dynamic tests Relative diameters determined by videodensitometry plotted against the internal diameters (in mm) of silastic tubes after injection of 3 ml contrast medium into water passing through the tubes in a steady flow Each point is the mean of 15 injections 5 injections each at three values of water flow in the tubes (10 _0 and 40 cm/s) The error is represented by a rectangle the height is twice the standard deviation the width is the uncertainty interval of the true diameter of a tube

Following the method described an amount of 3 ml contrast medium per injection is adequate for measuring diameters up to a maximum of 8 mm in tubes through which water is flowing (Fig 8)

The results of diameter measurements for the three water flow velocities (v=10 20 and 40 cm/s) and one quantity (q=3 ml) of injected contrast medium appear in Table 1 The table shows no correlation between the magnitude of the mean water velocity and the mean VDC value Similar tables drawn up for q=1 and 6 ml (not included here) lead to the same conclusion

The results of Table 1 are plotted in Fig 9 which is based on the mean values per group of 15 VDC values (relating to three settings of the water flow velocities and five repeated experiments per setting)

It is to be noted that the measured values in Fig 9 tally best with those in Fig 7 for a focal spot distance of 51 cm and a contrast medium concentration of 100 per cent Thus the static and the dynamic tests produce essentially the same results In practical terms the consequence of this agreement is that calibration procedures for in vivo experiments can be carried out with simple static test methods

In vivo experiment. The video tape with the 10 recordings of the 10 contrast medium injections into the aorta of the experimental animal was played back five times altogether. For each playback the window was shifted to another position along the image of the aorta on the monitor screen. The window positions chosen corresponded with the five lumbar vertebrae positions at which the check diameter measurements were made. Upon playback of each recording it was played back once again with the window position unchanged. Thus a group of 10×2 VDC values was obtained for each window position. These VDC values were calibrated with the aid of the experiments with the plastic calibration block and the wire guide. The VDC values M_{c1} and M_{c2} were measured on the images of the two contrast filled ducts in the calibration block with diameters D_{c1} and D_{c2} respectively. By linear interpolation a calibration relation was derived which relates the true diameter of the aorta D_a to the appertaining VDC value M_a. It reads

$$D_a=(D_{c2}-D_{c1})\frac{\delta M_a-M_{c1}}{M_{c2}-M_{c1}}+D_{c1}$$

in which $\delta=G_c/G_a$ is the ratio between the imaging scales G_c and G_a in the plane of the calibration block and the aorta respectively. The ratio δ was determined from the lengths of metal wire (length L_a= 20.0 mm) at the end of the wire guide in the aorta and of the length of copper wire (length L_c=30.0 mm) in the calibration block.

N_a and N_c are the numbers of horizontal TV lines which intersect the images of one of the lengths of mental wire and of the length of copper wire, respectively. Then $\delta=(N_c/L_c)/(N_a/L_a)$. Electronic counts on these images gave N_a=59 and N_c=94 from which it follows that δ=1.062.

Substitution of this value in the calibration relation and also of the known values D_{c1}=6.1 mm and D_{c2}=8.1 mm and of the measured VDC values M_{c1}=58 and M_{c2}=79 gives D_a=0.101 M_a+0.576. By means of this latter relation all VDC values (M) were converted into true diameter values in millimeters.

The aorta diameters obtained with the VDC (D_a) and with the intra arterial diameter sensor (D_a) on the five sites measured appear in Table 2.

Discussion

The results of diameter measurements in vivo in experiments with identical window position have a

Table 2

In vivo results. Comparison of the diameters of the a… d… measured with a calibrated videodensitometer… (D_a) and with an intra arterial sensor (D_a). D is the … of the results in n repeated injections

Location	n	VDC (mm) D	VDC (mm) SD	Diameter sensor (mm) D	D D (m…
L2/L3	10	7.31	0.10	7.44±0.10	0.13
L3/L4	20	7.19	0.23	7.24±0.04	0.05
L4	20	6.85	0.18	7.19±0.04	0.34
L4/L5	20	6.66	0.18	6.97±0.04	0.31
L5	20	6.71	0.20	6.80±0.04	0.09

standard deviation of approximately 0.2 mm irrespective of the selected window position (Table 2). This non reproducibility spread is the result of minor differences occurring in the course of contrast medium injection and the subsequent bolus formation and is also due to the mixing of quantum and electronic random noise in the image signal stemming from imaging system. Repetition of experiments will reduce the influence of the non reproducibility spread. If for example four experiments were to be repeated the standard deviation in the mean measured diameter value would be halved to 0.1 mm.

In addition systematic differences between the measured mean (VDC) diameter values D_a and the true (diameter control) diameter values D_a appear in Table 2. As the window position changes the amount of these differences fluctuates irregularly with an amplitude of 0.15 mm around an average of minus 0.2 mm. The explanation for the fluctuations about the average is a non homogeneous background in the form of organs and vertebrae which differs from one site to the other during exposure of the in vivo experiments. These background structures are superimposed on one another in the image; they influence the shape of the densitometric pulse of the image of the contrast filled blood vessel and thus cause errors in the result of the VDC diameter measurement.

Inaccurate calibration is the second source of systematic errors and is the result of employing a calibration relation lacking in precision. The latter in turn results from rounding off errors in the integrally measured values M_{c1}, M_{c2}, N_a, N_c (±0.5 units) and from measuring errors in D_{c1} and D_{c2} (±0.0… mm). The consequent error in the diameter determination can be calculated as maximum ±0.20 mm

a an error propagation analysis applied to the
alibration relation The average difference of 0 20
m referred to earlier can be explained (at least
artially) by this inaccurate calibration The afore
entioned systematic errors due to the non homo
neous background (±0 15 mm) and to inaccurate
alibration (±0 20 mm) add up to a total maximum
ystematic error to be expected in the diameter
easurement of ±0 35 mm (or approximately ±5%
n the measured aorta diameter of 7 to 8 mm)

A method enabling a more accurate calibration
o be made (not yet tested) consists of repeating the
alibration procedure employed but with the cali
ration block or wire guide being shifted each time
o a somewhat different distance between the tube
nd the image intensifier By averaging all the cali
ration values obtained a kind of average calibra
on relation can then be produced which may be
xpected to result in a smaller calibration error

The disturbing influence of the non homogeneous
ackground will diminish when the volume of a
ertain section of a blood vessel is to be determined
g for the purpose of determining the intensity
of blood flow by videodensitometry For the vessel
volume determination several blood vessel dia
meters are measured at different points along the
elevant section The errors in the individual dia
meter values resulting from the non homogeneous
background will then more or less average out so
that the volume will be determined with a higher
accuracy This advantage directly benefits the
videodensitometric dilution method in which a
blood vessel volume (V) is needed to calculate the
blood flow intensity (F) (from $F=V/\delta t$ where δt is a
mean transit time)

Conclusion

The described videodensitometric method is suit
able for measuring the internal diameters of con
trast filled blood vessels in all those parts of the
body where a catheter can be inserted Additional
conditions to be met for making absolute measure
ments are the following It must be possible to
replace the catheter temporarily by a special wire
guide and the blood vessel must lie plane parallel
with the image intensifier Another condition is that
the blood in the vessel at the measuring site is dis
placed by the injected contrast medium for arteries
of a diameter up to 8 mm the quantity required is
3 ml or less As a rule four repeated injections (at
intervals of about 5 min) are sufficient to achieve
satisfactory results Taking the photofluorographic
images as a basis and using the videodensitometric
equipment in conjunction with the adjustable win
dow diameters can be determined over a distance
of at least 10 cm along the vessel as was found
during measurements in the aorta of a dog (8 mm
diameter) Thanks to the videorecording of the
fluoroscopic images and the application of a special
computer which operates both automatically and
autonomously the diameter measurement is a rapid
and simple procedure

The range of measurement in which usable results
were obtained (as established with in vitro tests)
extends from 2 to 16 mm The maximum systematic
error that will occur under in vivo conditions is
±0 35 mm the standard deviation of the random
error is 0 20 mm These estimations of error are
based on duplicate measurements made in the aorta
of a dog (7 to 8 mm diameter) but they may also
be applied to the extended measuring range from 4
to 8 mm This is subject to the condition that the
determinations are made under comparable circum
stances such as the use of 3 ml contrast medium
per injection of a window with 14 TV lines and of a
calibration procedure as prescribed The random
error can be made arbitrarily small by repeating the
experiments It is anticipated that the maximum
systematic error can be halved by adopting a sug
gested improved method of calibration The error
diminishes even further when the average diameter
is determined over a certain length of a vessel (e g
for calculating the volume of a vascular segment)

SUMMARY

A method employing a special computer for determin
ing the internal diameters of blood vessels from photo-
fluorographic image is described in vitro and in vivo ex
periments are performed with the system The amount of
contrast medium injected is restricted to 4×3 ml and it
is possible to determine the diameter (in the range from
2 to 16 mm) at any place where blood vessels can be
catheterized In the in vivo experiments the maximum
systematic error is ±5 per cent in the 7 to 8 mm range

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IDIOPATHIC HYPERTROPHIC SUBAORTIC STENOSIS

II The shallow left ventricular cavity

G KVAM

The left ventricular cavity in idiopathic hyper rophic subaortic stenosis (IHSS) is rahter shallow EPSTEIN et coll 1974) Previously (Part I B KVAM 1980) it was shown that the hypertrophic IHSS inter ventricular septum does not bend towards the right ventricle during the systolic contraction As the sep tum does not shorten significantly neither length wise nor crosswise (Part I A) it was concluded that the septum acts as a suspender for the free ventric ular wall during the systolic contraction A larger percentage of the ventricular volume will thereby be ejected per per cent myocardial fibre shortening than ordinarily This effect is more marked when the ventricular cavity is rather shallow in a direction at right angles to the septal plane In the 60° right posterior oblique projection the direction of the ra diation beam is approximately parallel to the aver age septal plane If the ventricular cavity had a re duced depth it could be expected to appear shallow in this projection but this is not the case (Fig 1)

In the present report drawings of the ordinary diastolic 60 right posterior oblique outline and drawings made by a reduction method in the same projection as if the cavity was shallow are used in the biplane estimation of the end diastolic volume (EDV) according to the area length method These two estimates of EDV are compared with a third method the EDV calculated from the systolic ejec tion fraction (EF) and the stroke volume (SV) measured by a dye dilution technique

Materials and Methods

Biplane left ventricular cineangiographies at 75 frames per second from the same 4 IHSS and 15 control patients as in Part I were analysed

The angiography was performed as follows 40 to 45 ml Isopaque Coronar (370 mg I/ml Nyegaard Norway) were injected into the left ventricle using a pressure injector at 7 kg/cm and a William Cook pigtail catheter French 8 with side holes within 2 to 3 seconds In 2 of the patients with IHSS the injection time was slightly longer and in one who was given 30 ml 1 8 seconds

The series were exposed in the 30 right anterior oblique (RAO) and 60 right posterior oblique (RPO) positions

In 16 other patients biplane cineangiography was performed with an identical set up and with an iden tical catheter In both projections a metal grid positioned at right angles to the central ray was then exposed with the same focus-object and ob ject film distance at the centre of the left ventricular cavity previously exposed The catheter diameter on the film was measured in the aortic outflow tract when viewed under standard magnification Some blurring particularly in the 60° PRO view made exact measuring difficult However in both projec tions a linear correlation was found between the

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Fig 1 The end diastolic frame in the 60 right posterior oblique projection from a patient with IHSS

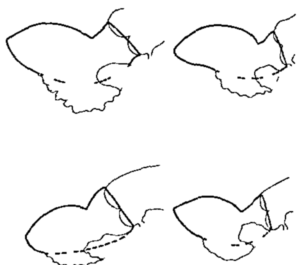


Fig 2 The 60 right posterior oblique outline of the left ventricular cavity from the 4 patients with IHSS drawn from the end diastolic cine frames The heavy lines (dashed and solid) show the outline drawn for the 60 right posterior oblique area when the reduction method was applied

catheter diameter and the enlargement factor of the grid when viewed with the same magnification The linear correlation coefficient was 0 74 in the 30° RAO view and 0 54 in the 60 RPO view (with the tube lateral t value for the latter 2 37)

The frames from the IHSS and the control patients were viewed with the same standard magnification The catheter was measured in the left ventricular outflow tract From the relationship described individual enlargement factors of the IHSS and the control films were calculated in both projections Both in the IHSS and in the control group an end diastolic and a consecutive end systolic frame were identified as the one with the largest and smallest ventricular area respectively before contraction or dilatation could be seen The ECG was not registered during the cardioangiography

The end diastolic volume was determined according to the biplane area length method (DODGE 1971) although the ellipsoid formula was used directly without any correction

In the IHSS group the 60 RPO area was also drawn according to a reduction method (dashed lines in Fig 2) The broken line was drawn across the valvar part of the cavity towards the dorsal part of the aortic root continuing the dorsal curvature of the apical part When using this alternative area the volume was in all other respects calculated according to the same method as mentioned

The ejection fraction was calculated according to the 30 RAO uniplane area length method using midaortic axes

$$EF = \frac{\frac{Ad}{Ld} - \frac{As}{Ls}}{\frac{Ad}{Ld}}$$

Ad As Ld and Ls are the diastolic and systolic areas and diastolic and systolic midaortic lengths respectively directly as observed the enlargement factor being eliminated in the formula

The stroke volume was measured by a dye dilution technique (Stewart Hamilton) and the end diastolic volume of the left ventricle was then also calculated according to the SV/EF method

Results

The different values for EDV are given in the Table Individual values are given for the IHSS patients the mean values ranges of values and standard deviations for the control group

In the IHSS group a paired t test shows that a significant methodologic difference exists between the ordinary biplane method and the SV/EF method for calculating EDV(t=2 75 p<0 05) but no difference between the reduction method and the SV/EF method for calculating EDV

In the control group a paired t test shows that

Table

[E]nd diastolic volume in the 4 patients with IHSS individual and [m]ean values measured by an ordinary biplane method a biplane [m]ethod according to the reduction method described and by a [m]ethod implying dividing the stroke volume (estimated by a dye [di]lution technique) by the systolic ejection fraction In the control [gro]up the volumes estimated by the first and the last of these [m]ethods are presented as mean values ranges of values and standard deviation

	End diastolic volume		
	Biplane method	Biplane reduction method	SV_d /EF method
HSS group			
Individual values	170	130	110
	174	103	112
	139	114	1_5
	14	117	90
Mean values	144	116	109
ontrol group			
Mean values	165		155
Ranges	13 –227		87–227
Standard deviation	28		38

makes no difference whether EDV is measured according to the ordinary biplane method or according to the SV/EF method

Discussion

Among the present 4 IHSS patients an ordinary biplane volumetric calculation from the 30 RAO and the 60° RPO cine views overestimates EDV systematically

In the formula for the EDV calculation the area in the 30 RAO projection and the depth in the 60 RPO projection are used The 60 RPO depth D is calculated according to the formula D=4 A/π L where A is the area and L the greatest length in the 60 RPO projection The depth is thus calculated from the formula of the ellipse A significant indentation of a structure into the area not registered in the area measurement because of superimposition therefore causes a systematic overestimation of the overall depth and thus of the volume The IHSS hypertrophic septum is such a structure

CONN et coll (1966) reported an average EDV of 1?? ml among 15 IHSS patients while their controls had an average EDV of 133 ml a difference between the means of about 8 per cent They used a biplane angiographic method

GOTSMAN & LEWIS (1974) reported an average EDV of 66 ml/m among 14 patients with IHSS and 70 ml/m among controls a difference between the means about 6 per cent They used uniplane RAO for estimating the volume which presupposes a normal relationship between the 30 RAO width and the 60 RPO depth

The present patients with IHSS had a mean EDV 11 to 12 per cent smaller than the controls when different ordinary area length methods were applied When the reduction method was applied the difference was nearly 30 per cent

Assuming that CONN et coll and GOTSMAN & LEWIS investigated patients with the same morphologic characteristics as the present patients they have overestimated the EDV in their IHSS groups

Conclusion The IHSS left ventricular cavity is shallow even though it does not have this appearance in the 60 RPO projection The EDV is overestimated in IHSS with ordinary angiographic volumetric methods because the influence of the hypertrophic bulging muscular interventricular septum is neglected

SUMMARY

Using different volumetric methods for the estimation of the end diastolic volume in patients with idiopathic hypertrophic subaortic stenosis it is concluded that in this condition the left ventricular cavity is shallower than it appears in the 60° right posterior oblique projection and that ordinary cardioangiographic volumetric methods probably overestimate the end diastolic volume because of the septal bulge

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ANGIOGRAPHY AND ULTRASOUND EXAMINATION IN THE EVALUATION OF PANCREATIC LESIONS

W KARP A LUNDERQUIST U TYLÉN and I IHSE

Until recently angiography of the pancreas was one of the first diagnostic procedures used when pancreatic abnormality was clinically suggested However new methods such as ultrasound computer tomography and ERCP have been introduced and in order to find their proper place in the examination of pancreatic diseases these methods must be compared with those previously established In this report ultrasound and angiography are compared in a group of patients examined with both methods

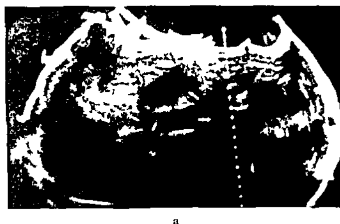
Material and Methods

The experience is based on 380 examinations of the pancreas using gray scale ultrasound Only patients in whom both ultrasound and angiography of the pancreas were performed within a period of one and a half year were included in the present series which consisted of 68 patients 24 females and 44 males 20 to 77 years of age The clinical diagnosis was carcinoma in 23 chronic pancreatitis in 19 pseudocyst in 3 and insulinoma in one patient The diagnosis of carcinoma and pseudocyst was confirmed by operation and microscopic examination The insulinoma was also confirmed at operation The diagnosis of chronic pancreatitis was based on clinical data supported by ERCP in 7 cases In the remaining 22 patients examined in most cases because of abdominal pain no clinical evidence of pancreatic disease was found on follow up of more than 6 months

Ultrasound was usually performed before angiography An ultrasound unit with gray scale and focused transducers of 13 and 19 mm diameter 2 25 and 3 5 MHz was used A standard technique of examination (SAMPLE et coll 1975 CARLSEN & FILLY 1976 DOUST & PEARCE 1976 WEILL et coll 1977) was employed including transversal longitudinal and oblique scans sometimes with the transducer angled about 10° caudally or cranially in an effort to avoid bowel gas Single pass technique was used Examination of the tail of the pancreas through the left kidney was always made (GOLDSTEIN & KATRAGADA 1978)

The pancreatic area was located by anatomic landmarks mainly the vascular structures The results of the ultrasound examination were classified as normal when the pancreas was of normal size or when it could not be directly demonstrated despite optimum conditions The pancreas was also considered normal if no mass could be demonstrated in this area (*SAMPLE et coll DI MAGNO et coll 1977*) The examination was regarded as abnormal when the antero posterior diameter of the gland was more than 3 cm and when echo abnormalities were observed An attempt to make a specific diagnosis of carcinoma pseudocyst or pancreatitis was also made The criteria suggesting chronic pancreatitis were diffuse or local enlargement of the gland with

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a



b

Fig 1 Male aged 67 Operation revealed chronic pancreatitis a) Transverse b) longitudinal scan Mass in head of pancreas (→) with decreased echogeneicity Aorta (↔) and A) Inferior v cava (↔)

scattering of the internal echoes which were usually of decreased intensity (Fig 1) Occasionally strong echoes associated with acoustic shadowing typical for calcification suggested the diagnosis of chronic pancreatitis Pancreatic carcinoma was diagnosed in the presence of a solid mass which was indistinctly outlined and with few internal echoes (Fig 2) An echo free structure with more or less regular posterior wall was regarded as representing pancreatic pseudocyst (Fig 3)

Selective angiography was performed by simultaneous injection into the coeliac and superior mesenteric arteries including a series with vasodilating agent in the superior mesenteric artery for better demonstration of the veins Superselective examination was performed in 26 patients

The results of the angiography were classified as normal or abnormal A specific diagnosis of chronic pancreatitis pseudocyst or carcinoma was attempted in all patients The criteria for chro pancreatitis were vascular alterations consisting smooth regular arterial stenosis irregularity a tortuosity of pancreatic arteries The abnormalit in chronic pancreatitis were usually extensive wh in carcinoma they were more localized The vasc lar alterations suggesting pancreatic carcinoma co sisted of encasement irregularity of the arter and presence of abnormal vessels Involvement the veins was regarded as specific neither for mal nancy nor for chronic pancreatitis The diagnosis pseudocyst was based on displacement of the teries due to an avascular expanding lesion

Evaluation of the ultrasound and angiograp examinations was made independently by seve experienced radiologists and the first conclusi was regarded as definitive The results of bo examinations were later correlated with the surgi findings or clinical follow up

Table 1

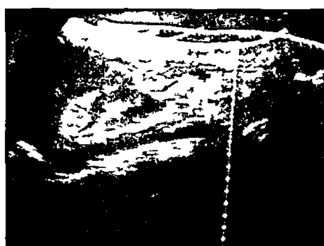
Ultrasound in 62 patients (6 examinations unsatisfactory due to intestinal gas)

	No of cases	Correct diagnosis	Incorrect diagnosis	Accuracy (per cent)
Normal pancreas	18	18	–	100
Pancreatic carcinoma	22	15	7	68
Chronic pancreatitis	18	4	14	22
Pseudocyst	3	3	–	100
Insulinoma	1	–	1	
Total	62	40 (64 5%)	22 (35 4 %)	

One incorrectly considered as chronic pancreatitis
Two incorrectly considered as pancreatic carcinoma



a



b

Fig 2 Female aged 76 with carcinoma of the body of the pancreas a) Transverse b) longitudinal scan Mass in body of pancreas (→) with alteration of the echoes (echo-intensity increased centrally in mass and decreased peripherally) Aorta (↔)



a



b

Fig 3 Male aged 70 with pseudocyst in the head of the pancreas a) Transverse b) longitudinal scan Echo-free expansivity in head and body of pancreas Inferior vena cava is compressed (→) K=right kidney

Results

Six of the 68 ultrasound examinations were unsatisfactory because of the presence of too much intestinal gas All of the angiographic examinations were satisfactory The results of the ultrasound and angiographic examinations are summarized in Tables 1 and 2 Ultrasound had an overall diagnostic accuracy of 64 5 per cent and angiography 76 4 per cent

In 15 of the 23 patients with pancreatic carcinoma the correct diagnosis was made by both methods (Fig 4) In 2 patients the carcinoma was overlooked at both methods and in 5 cases the pancreas was reported normal on ultrasound but the tumour was correctly diagnosed on angiography In one patient the ultrasound examination was unsatisfactory due to bowel gas (pancreatic carcinoma found at angiography)

The size of the mass in the pancreas estimated at surgery ranged in cm from 2 5×2 to 7×4 Two carcinomas overlooked at ultrasound had diameters of about 7 cm one of 4 one of 3 and two of about 2 cm The one carcinoma incorrectly considered as chronic pancreatitis was 6 cm×4 cm Two on angiography overlooked carcinomas had diameters of 3 cm and 2 cm respectively In all patients but one the mass was located in the head or body and in one patient in body and tail

The ultrasound and angiographic examinations were compared in 18 of the 19 patients with chronic pancreatitis In one patient the ultrasound examination was unsatisfactory due to bowel gas In 4 of the

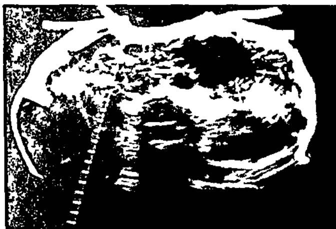


Fig 4a



Fig 5



Fig 4b

Fig 4 Female aged 76 with carcinoma of the body and tail of the pancreas a) Transverse scan Echo-free mass in the body and tail of pancreas (→) Aorta (↔) Inferior vena cava (↔) b) Select simultaneous angiography of coeliac and superior mesenteric arteries Slightly irregular lumen of hepatic and splenic arteries Occlusion of middle part of splenic artery Pathologic vessels adjacent to the occlusion Collateral circulation in left gastric artery to the spleen

Fig 5 Male aged 54 with chronic pancreatitis Longitudinal scan Echo-free mass in head of pancreas with strong echoes (→) and acoustic shadowing (→) due to calcifications Puncture revealed cystic fluid collection

patients correct diagnosis was made on ultrasound and in only one of these by both methods (Figs 5 6) In 3 of these 4 patients angiography failed to demonstrate any lesion In 6 patients with correct angiographic diagnosis ultrasound failed to demonstrate any lesion in the pancreas In 2 cases chronic pancreatitis erroneously was considered at both methods as pancreatic carcinoma In 3 cases incorrectly diagnosed at angiography as pancreatic carcinoma ultrasound failed to demonstrate any lesion In the remaining 3 patients pancreatic lesion was overlooked at both methods

All 3 pseudocysts were correctly diagnosed on ultrasound and 2 on angiography Angiography suggested chronic pancreatitis without pseudocyst formation in one instance

Neither on ultrasound nor angiography was the insulinoma demonstrated

All patients with a normal pancreas were diagnosed correctly with ultrasound as well as angiography However cases erroneously considered as normal occurred with both methods Thus the predictive value of a normal condition was at ultrasound 45 per cent and at angiography 57 9 per





a b

Fig 6 Same case as in Fig 5 Selective simultaneous angiography of coeliac and superior mesenteric arteries a) A p and b) oblique view Displacement of gastroduodenal artery and pancreatic arcades surrounding avascular expansivity Calcification in head of pancreas

cent The falsely normal findings were mainly due to false evaluation of chronic pancreatitis

Discussion

Previously it was generally agreed that a normal pancreas could not be demonstrated with ultrasound (FILLY & FREIMANIS 1970 BURGER & BLAUENSTEIN 1974 WALLS et coll 1975) However progress in ultrasound technology with the use of gray scale has made it possible to outline the pancreas (DOUST & PEARCE HANCKE 1976 HABER et coll 1976 WEILL et coll)

The normal pancreas appears as an echo-producing structure with echoes similar to those of the liver These echoes can be slightly stronger than those of the liver depending on the kind of equipment used The pancreas is located in close anatomic relationship to the large abdominal vessels (LEOPOLD 1975 a b GHORASHI & RECTOR 1977) which are easily demonstrated by ultrasound (Fig 7) Nevertheless the normal pancreas is sometimes

Table 2

Angiography in 68 patients

	No of cases	Correct diagnosis	Incorrect diagnosis	Accuracy (per cent)
Normal pancreas	22	22	–	100
Pancreatic carcinoma	23	21	2	91
Chronic pancreatitis	19	7	12	36 8
Pseudocyst	3	2	1	66 6
Insulinoma	1	–	1	
Total	68	5 (76 4%)	16 (23.5%)	

Five incorrectly considered as pancreatic carcinoma

One incorrectly considered as chronic pancreatitis without pseudocyst



a



b

Fig 7 Transverse scan through pancreatic area a) Male aged 78 b) male aged 43 L=liver Pancreas (→) Aorta (↔) Superior mesenteric artery (↠) Portal vein (↤) Splenic vein (↣)

difficult to demonstrate The size and configuration of the left liver lobe are in this respect of great importance as the lobe can sometimes be used as sonic window (HANCKE) A great disadvantage is that ultrasound is greatly hampered by obesity and intestinal gas Pharmacologic agents such as Simethicone have been tried to reduce the amount of gas (PEPPER & KEENE 1976 SOMMER et coll 1977) Filling of the stomach with water in an effort to displace the gas (KOBAYASHI 1971 CRADE et coll 1978) has been tried but all these attempts have been without great success The best alternative seems to be to repeat the examination another day

The echographic size of the normal pancreas is subject to discussion (HANCKE HABER et coll GARDFUR et coll 1976 WEILL et coll) Great individual variations exist with a tendency for the pancreas to be larger in young people (GHORASHI & RECTOR WEILL et coll) In this series the proposal was accepted that an antero posterior diameter of more than 3 cm indicates abnormality (HANCKE WEILL et coll) WEILL (1978) has considered the mean thickness of the pancreatic head to be 17 mm (range 11 to 30 mm) body 10 mm (range 4 to 20 mm) and tail 17 mm (range 7 to 28 mm) on ultrasound These findings are in accordance with results from dissection and computer tomography (HAERTEL & KREEL 1978) However it appears that measurements alone are of limited value because of great individual variations other factors such as the appearance of the echoes and the outline of the organ are more important in the assessment of the findings

Although 7 cases were missed the accuracy of ultrasound was higher in the diagnosis of carcinoma than of chronic pancreatitis This also applies for angiography (REUTER et coll 1969 TYLÉN & ARNESJÖ 1973 a) At angiography 91 per cent of carcinomas (106 of 116 patients) were identified and moreover gave information as to resectability (TYLÉN & ARNESJÖ 1973 b) With the exception of pseudocyst where ultrasound seems to be an ideal method angiography should therefore be the method of choice in the diagnosis of pancreatic disease However demonstration of a normal pancreas with ultrasound is of great value This fact makes the method suitable for the screening of patients with abdominal pain in whom pancreatic disease is less probable Furthermore the method is noninvasive and without radiation risk

Very small carcinomas may sometimes be defined at angiography through the demonstration of local encasement Ultrasound mainly demonstrates lesions which deform the outline of the gland Both carcinoma of the pancreas and chronic pancreatitis may enlarge the gland and if such enlargement is localized differentiation between the two diseases may be difficult (HANCKE LEVITT et coll 1978 MULLENS & SALEM 1978) In the present series both small and large carcinomas were missed the size per se seems therefore not to be important Alterations of the echo appearances may also be of help (LEOPOLD HUSBAND et coll 1977 WOOD et coll 1976)

The echo appearance of the gland looses the normal homogeneity in carcinoma of the pancreas increase as well as decrease in echo intensity may occur in comparison with normal pancreatic echoes However increase was rare in the present series This observation agrees with that of JOHNSON & MACK (1978) who claim that an increase in echo-intensity supports the diagnosis of chronic pancreatitis

in an atrophic gland The presence of calcifications or pseudocysts which often accompany chronic ...atitis can also be of value for establishing the correct diagnosis Secondary abnormalities such as dilatation of the biliary ducts hepatic metastases ...d ascites can be diagnosed with ultrasound and can also contribute to the differentiation

A pseudocyst which often appears as an echo free ...ture may have scattered echoes inside due to ...is Such a pseudocyst may be overlooked if smaller than 2 cm SOKOLOFF et coll (1974) have reported that it may be difficult to differentiate acute pancreatitis from a pseudocyst because the pancreas may appear as an echo free structure due to oedema However generally the diagnosis of pseudocyst is easy and accurate An 87 5 per cent accuracy in the diagnosis of uncomplicated pseudocyst was found by KRESSEL et coll (1978)

Similar differential diagnostic difficulties are well known in all other methods employed in the diagnosis of pancreatic disease A specific diagnosis can only be suggested after demonstration of a pathologic condition in the pancreas It should be confirmed by percutaneous fine needle biopsy guided by the ultrasound finding (ISAACSON et coll 1974 SMITH et coll 1975 HANCKE et coll 1975) The success rate of fine needle biopsy guided by ultrasound is 70 per cent according to HANCKE et coll and 61 per cent according to TRILLER et coll (1978) The success rate of biopsy guided by angiography varies from 60 to 75 per cent (OSCARSON et coll 1972 TYLÉN et coll 1976 CLOUSE et coll 1977 EVANDER et coll 1978)

The reported accuracy of ultrasound in the diagnosis of pancreatic disease varies from 73 to 91 per cent (FILLY & FREIMANIS HAAGA et coll 1976 1976 HANCKE et coll) The accuracy in the present series was 64 5 cer cent if unsatisfactory examinations are eliminated This is to be compared with an accuracy rate of 76 4 per cent with angiography However recent developments in ultrasound imaging techniques have improved the diagnostic results BRAGANZA et coll (1978) presented a material with a low rate of erroneous normal and pathologic ultrasound results in examination of pancreatic lesions and concluded that this method is valuable in screening when pancreatic disease is suggested

Ultrasound is a valuable and simple screening method to be used in pancreatic disease Computer tomography if available is an important complementary method (HAAGA et coll 1977 GO & SCHEEDY 1978 KRESSEL et coll) Angiography will be used mainly to predict prognosis and operability in selected cases (FREENY & BALL 1978) The diagnosis of chronic pancreatitis is still difficult with these methods as well as with angiography ERCP must therefore be regarded as an important additional method in patients with possible pancreatic disease (WOOD et coll 1976)

SUMMARY

Ultrasound and angiography of the pancreas were performed in 68 patients Ultrasound reached an accuracy of 64 5 per cent and angiography 76 4 per cent Both methods excluded disease of the gland in all patients without clinical evidence of disease at follow up Both methods had higher accuracy in the diagnosis of carcinoma than of pancreatitis Although angiography has higher accuracy ultrasound is recommended for screening of patients with abdominal pain Because of the differential diagnostic difficulties percutaneous fine needle biopsy is recommended when a pancreatic lesion is demonstrated Angiography is used mainly to predict operability and prognosis

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SELECTIVE VEIN CATHETERIZATION FOR HORMONE ASSAY IN ENDOCRINE TUMOURS OF THE PANCREAS

Technique and results

W REICHARDT and S INGEMANSSON

The morphology of the pancreas can be examined using different techniques such as scintigraphy ultrasound computer tomography angiography and phlebography Active endocrine tumours are often too small to be detected with most of these methods Successful localization of insulinomas by computer tomography has been reported in a few cases (FRICKE et coll 1978) Best results of the imaging techniques are obtained with angiography The reported accuracy varies widely between 20 and 100 per cent (BOOKSTEIN & OBERMAN 1966 BOIJSEN & SAMUELSSON 1970 SKJOLDBORG & MADSEN 1971 FUJII et coll 1974) The majority of authors account for about 80 per cent positive angiographic diagnoses in patients with proved insulinomas However GRAY et coll (1970) pointed out that the angiographic accuracy in series comparing positive and negative findings was 63 per cent

Selective vein catheterization with hormone assay is since long used for diagnosis and localization of parathyroid and adrenal tumours The percutaneous transhepatic approach to the portal vein (WIECHEL 1971) made an extensive selective catheterization of the pancreatic veins feasible (LUNDERQUIST & TYLÉN 1975) It has been demonstrated that localization of insulin glucagon gastrin and serotonin producing tumours of the pancreas by arteriovenous hormone gradients is possible (INGEMANSSON 1977) The method has proven to be sensible enough to locate microscopic lesions as islet cell hyperplasia (INGEMANSSON et coll 1977) The present report summarizes the pertinent anatomy of the pancreatic veins describes the technique of selective catheterization and accounts for the results

As the venous anatomy of the pancreas has been described in detail previously (REICHARDT & CAMERON 1980) only a short summary is given here (Fig 1)

The venous drainage of the pancreas is varying Most constant is the venous anatomy of the head of the pancreas The anterior superior pancreaticoduodenal vein is draining the ventral part of the head joining the gastrocolic trunk which is ending in the superior mesenteric vein The dorsum of the head is drained by the posterior superior pancreaticoduodenal vein which empties into the dorsolateral aspect of the portal vein The post sup vein may be double or even triple In these instances one of these veins may drain a ventrocranial part of the head of the pancreas The veins of the uncinate process are ventrally connected in an anterior inferior pancreaticoduodenal vein and dorsally in a posterior inferior pancreaticoduodenal vein Both end into the superior mesenteric or the first jejunal vein Often a ventral and a dorsal arcade are running in the pancreaticoduodenal sulcus along the duodenal loop connecting the main veins of the head

The body of the pancreas is often drained by a transverse pancreatic vein ending in the inferior mesenteric superior mesenteric or splenic vein Furthermore small branches can join the coronary vein or end in the post sup vein Veins of the body

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may even drain directly into the splenic vein as the veins of the tail of the pancreas Sometimes a vein of the distal part of the tail ends in a lower polar vein of the spleen

Material

From January 1974 until November 1978 45 triple catheterizations of the pancreatic veins were performed in 32 patients 17 females and 15 males aged 23 to 70 years Fourteen patients were examined in order to locate clinically and laboratory confirmed endocrine tumours of the pancreas (7 patients with hyperinsulinism 4 patients with Zollinger–Ellison syndrome 3 patients with glucagonoma syndrome) Thirteen examinations were performed postoperatively to confirm surgical radicality or to locate recurrences In 18 patients catheterization was employed to diagnose and locate or to exclude endocrine tumours when clinical symptoms suggested this diagnosis but laboratory findings were non conclusive

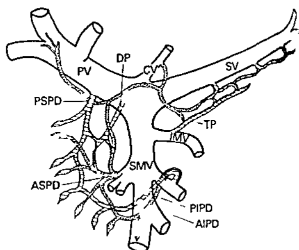


Fig 1 Venous anatomy of the pancreas schematic PV portal vein SV = splenic vein SMV = superior mesenteric vein IMV = inferior mesenteric vein PSPD = posterior superior pancreaticoduodenal vein ASPD = anterior superior pancreaticoduodenal vein PIPD = posterior inferior pancreaticoduodenal vein AIPD = anterior inferior pancreaticoduodenal vein TP = transverse pancreatic vein DP dorsal pancreatic vein CV = coronary vein The dotted veins are anterior the striped veins posterior to the pancreas

Methods

Catheterization technique

Percutaneous transhepatic puncture of the portal vein was performed according to the technique introduced by WIECHEL and described in detail previously (GÖTHLIN et coll 1974 HOEVELS et coll 1978) Using a 25 cm long needle (Surgimed Denmark) coated with a polyethylene catheter (OD 1 6 mm ID 1 0 mm) the puncture was performed in the right midaxillary line towards the hilum of the liver The needle was withdrawn and the catheter slowly pulled back until blood could be aspirated without resistance After injection of a small amount of contrast medium during fluoroscopy to assure the correct position in a portal vein branch a guide wire with soft tip was manipulated into the portal vein The catheter was then pushed over the guide wire into the same position

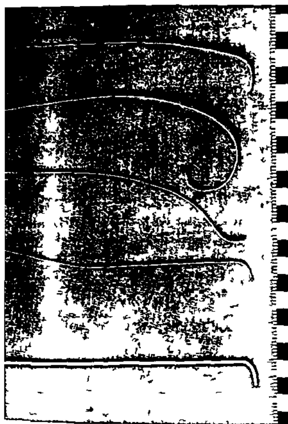
A cranially directed puncture was avoided as a sharp intrahepatic angle of the catheter would be the result and the further catheterization procedures would be difficult A puncture directed in a right angle to the spine or slightly caudally was preferred The latter was often practicable in elderly patients without risk to hurt the lung

All catheterizations were performed using a 0 9 mm guide wire (Surgimed Denmark) with a soft tip but stiff enough to be formed by hand according to the desired course of the catheter This guide wire was also stiff enough to allow the catheter to be pushed over it without leaving its position in a portal vein tributary Catheterization procedures with the catheter alone were strictly avoided as they could result in injury to the vessel wall and subsequent extravasation of contrast medium For the same reason the catheter should not be allowed to advance beyond the tip of the guide wire

A series of 16 films was exposed (5 films/s 8 films/4 s 3 films/6 s) after injection of 40 ml of Isopaque Coronar 370 mg I/ml (Nyegaard Norway) at a rate of 8 ml/s into the superior mesenteric vein or splenic vein to document the position of the main tributaries of the portal vein and to examine the parenchyma of the liver

Selective catheterization of the pancreatic veins was started with a main vein of the head the posterior or the anterior superior pancreaticoduodenal vein

A 2 cm long curve of the tip of the guide wire (Fig 2 a) was as a rule usable to enter the post sup vein which could be found in the dorsocaudal wall of the portal vein within 2 5 cm from the confluence of the superior mesenteric and splenic vein (in the following text called confluence) After successful manipulation of the guide wire into the post sup vein the catheter was pushed over it



Various shapes of guide wires used for selective heterization of a) post sup vein b) ant sup vein c) trans se pancreatic vein d) veins of the tail e) Shape of catheter d for catheterization of veins of the tail side hole close to the

During fluoroscopy a small amount of contrast edium was injected to assure a correct position of e catheter After having emptied the contrast me um out of the catheter a blood sample could be thdrawn

A phlebography was performed to document the lace of blood sampling and to chart the venous natomy Into a post sup pancreaticoduodenal vein f normal caliber about 6 to 8 ml of contrast medium as injected by hand Eight films were exposed 2 ilms/s In general several adjacent veins of the ead of the pancreas and the inflow of the ant sup nd inf rior veins into the main tributaries of the ortal vein system were demonstrated on these films Fig 3) Knowing the topography of the veins an dequate shape of the guide wire could be formed nd catheterization was facilitated Catheterization of the ant sup vein demanded in general an almost ircular shape of the tip of the guide wire with a diameter of about 3 to 4 cm (Fig 2b)

The transverse pancreatic vein was searched for in the left lateral wall of the superior mesenteric vein near the confluence in the left lateral wall of the inferior mesenteric vein or caudally in the splenic vein near the confluence An example of a usable shape of the guide wire for catheterization of this vein appears in Fig 2c

The main veins of the body were often demon strated when contrast medium was injected into a pancreatic vein draining to the splenic vein Thus knowing their course selective catheterization of these veins could usually be made (Fig 4)

The veins of the tail of the pancreas usually can be entered in the ventrocaudal circumference of the splenic vein using a 1 to 1 5 cm long curve at the tip of the guide wire (Fig 2d) *Sometimes the guide* wire slips out of the vein when the catheter is pushed over it In these instances it can be helpful to preshape the catheter with an about 1 cm long curve (Fig 2e) For catheterization of the veins of the tail the 25 cm long catheter as a rule had to be replaced by a 40 cm long one In corpulent patients some times even catheterization of the ant sup pancrea ticoduodenal vein demanded the longer catheter

Blood sampling and injection of contrast medium in small pancreatic veins was facilitated by a side hole close to the tip (Fig 2e)

The amount of contrast medium used for filling of the veins of the body and tail depended on the size of the vessels and varied between 2 and 8 ml All injec tions were made by hand

Blood sampling technique

After 8 to 10 hours of fasting catheterization of the coeliac artery hepatic veins and portal vein was performed

Samples were taken from all 3 catheters at the beginning and the end of the examination some times even once more during the catheterization procedure In the portal vein system samples were withdrawn at 2 or 3 levels of the splenic superior mesenteric and portal veins

Selective catheterization of the post and ant su perior pancreaticoduodenal vein and the transverse pancreatic or corresponding vein of the body and one or two veins of the tail was always aimed at At the beginning when the knowledge of pancreatic vein topography was limited the success rate of se lective catheterization was about 2 veins per exam ination Later examinations comprised 4 to 6 se lectively catheterized pancreatic veins In smaller



a



b



c

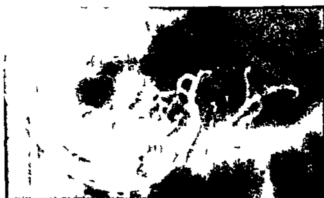


d

Fig 3 Stepwise selective catheterization in a patient with unusual anatomy a) Injection into post sup vein Via collaterals filling of ant sup vein which drains to the right branch of a double sup mesenteric vein Ant inf vein (→) Post inf vein (↔) ending in the left branch of the double sup mesenteric vein (↔) b) Injection into ant sup vein Via collaterals filling of post sup vein and veins of hepatoduodenal ligament c) Injection [illegible] ant sup vein the catheter more caudally directed Gastro[illegible] ploic vein (→) vein to the right colon (↔) and ant inf vein [illegible] filled d) Injection into ant inf vein Filling of ant sup (→) [illegible] post inf (↔) veins



a



b

Fig 4 Same case as in Fig 3 a) Injection into a vein of the tail draining to splenic vein Inflow of a vein of the body (→) b) Injection into this vein of the body results in filling of other veins of the body which have an unusual location cranial to the confluence Veins of the body are draining to the cranial circumference of the region of the confluence

pancreatic veins blood samples could not be withdrawn but were obtained by dripping From the portal vein system 8 to 30 blood samples were taken for hormone assay

Angiography

In all cases an examination including simultaneous coeliac and superior mesenteric artery injection superselective injections of the gastroduodenal or common hepatic artery and splenic artery were aimed at but performed only in 14 In one of these even the dorsal pancreatic artery was examined In 1? patients the coeliac superior mesenteric and either gastroduodenal or splenic or inferior pancreaticoduodenal artery was injected In 5 patients only coeliac and superior mesenteric angiography was obtained due to anatomic conditions or morphologic abnormalities such as coeliac artery stenosis which made more selective catheterization impossible

Radioimmunologic techniques

Blood samples for radioimmunoassay of gastrin vasoactive intestinal polypeptide and insulin were collected centrifuged and sera were stored at −20°C until assayed Blood samples for radioimmunoassay of glucagon and somatostatin were collected in tubes containing trasylol and heparin (for references see INGEMANSSON)

Surgery

At exploratory laparotomy the pancreas was palpated and inspected carefully Dissection was performed in a way that the pancreatic veins could be identified and compared to the phlebographic findings Resections of the pancreas were performed according to angiographic findings the venous and phlebographic anatomy as well as the arteriovenous hormone differences

Tissue analysis Tissue specimens obtained at surgery were processed for immunocytochemistry (for references see INGEMANSSON)

Results

Angiography

Two of 5 insulin producing tumours were correctly demonstrated at angiography In one case a hypervascular lesion 1 cm in diameter in the body and furthermore a hypervascular lesion in the hilum of the spleen were found The latter was correctly considered as an accessory spleen In the other case a hypervascular lesion adjacent to an avascular expanding lesion with a diameter of 10 cm was found The latter turned out to be a cyst No angiographic abnormality was found in 3 patients with insulinomas and in 2 patients with B-cell hyperplasia

In 3 patients with multiple gastrin producing tumours angiography revealed one tumour (1 5 cm×2 5 cm) in one patient two 6 mm large tumours in the second patient and was suggestive of further two 3 mm large tumours No abnormality was found in the third patient In the fourth patient with Zollinger–Ellison syndrome a 1 5 cm hypervascular lesion was demonstrated in the body of the pancreas The patient refused surgery and thus the tumour is not confirmed

In 3 patients with glucagonoma syndrome the tumours were located by angiography in 2 The size of the tumours was 5 cm and 4 cm respectively in the

third patient a hypervascular lesion 6 mm in diameter in the head of the pancreas was found retrospectively (Fig 5)

In one patient with a 9 year history of diarrhoea a hypervascular tumour 6 cm in diameter was demonstrated in the head of the pancreas This tumour contained and released somatostatin

In one patient with heredity for multiple endocrine adenomatosis and previously operated upon for parathyroid adenoma a hypervascular tumour 2 cm in diameter was demonstrated At surgery this tumour and an additional tumour 4 mm in diameter were found These tumours could not be classified by immunocytochemistry but were classified as D_1 cell tumours by electron microscopy

In 15 patients without confirmed tumours the angiography was normal

Phlebography

Three tumours 4 5 and 6 cm in diameter as well as the cyst 10 cm in diameter could be demonstrated as expanding lesions with displacement of the veins (Fig 6) The other tumours were less than 2 cm in diameter and were not observed at phlebography In one patient previously operated upon a branch from the ant sup pancreaticoduodenal vein was obliterated probably ligated

At postoperative examinations in patients with enucleated islet cell tumours no morphologic abnormalities were demonstrated In patients with hemipancreatectomy only ligation of the splenic vein was found and no abnormalities at selective phlebography of the remaining pancreatic tissue (Fig 7)

Hormone analyses

Detailed results of hormone analyses have been published previously (INGEMANSSON et coll 1975 1977 1978 REICHARDT et coll 1979) and are therefore only summarized here

Insulin producing tumours and islet cell hyperplasias Seven patients 2 with B-cell hyperplasia and 5 with B-cell adenomas were examined In 2 patients islet cell hyperplasia in the tail and in the body of the pancreas respectively was correctly located by arteriovenous insulin concentration gradients In 3 of 5 patients with B cell adenomas the tumours were correctly located 2 in the body and one in the tail of the pancreas

In one patient with hyperinsulinism operated upon twice with partial resection of the pancreas and



Fig 5 Glucagonoma of the head of the pancreas Injection gastroduodenal artery parenchymal phase Small hypervascular lesion (→)

ligation of the splenic vein high insulin concentration was found in an anastomosing vein between the hilum of the spleen and the superior mesenteric vein At laparotomy an insulinoma was found in the remaining part of the tail In one patient with an insulinoma in the dorsocranial part of the head of the pancreas the tumour could not be located by arteriovenous hormone differences though the sampling procedures were performed twice

Gastrin producing tumours Four patients with Zollinger–Ellison syndrome were examined In ? the gastrin concentration was increased in general in the portal vein system and the analyses could not locate the tumours At operation performed within 6 weeks after sampling multiple tumours were found within and around the pancreas In one patient 2 examinations were performed after total gastrectomy and enucleation of a gastrinoma gastrin concentrations were normal An examination 4 5 years after gastrectomy revealed increased gastrin concentrations in all veins in the region of the pancreas with a maximum in the post sup pancreaticoduodenal vein At operation one tumour in the head 1 cm in diameter and multiple small tumours in the body and tail were found In one patient all gastrin concentrations were increased with a maximum in the post sup vein The patient refused surgery

Glucagon producing tumours Three patients with glucagonoma syndrome were examined All glucagon producing tumours were correctly loca-



Fig 6a



Fig 6b



Fig 7

Fig 6 Tumour of the head of the pancreas 5 cm in diameter a) Injection into the common hepatic artery parenchymal phase b) Phlebography of the head Slight curved displacement of the veins (→)

Fig 7 Selective phlebography of the body of the pancreas in a patient in whom the tail has been resected No morphologic abnormality

by arteriovenous hormone gradients 2 in the head and one in the tail of the pancreas In one patient with a tumour in the head of the pancreas the tumour even contained insulin and serotonin and furthermore insulin concentrations were increased in the veins of the tail Resection of the tail was performed No hyperplasia or adenoma was found at light microscopy Parts of the tissue were also examined by electron microscopy and immunochemistry even then without pathologic findings

Other tumours One tumour of the head of the pancreas could not be classified preoperatively

Table

Hormone concentrations in tumour draining veins compared with the portal vein tributary outside the tumour draining veins

	Hormone concentration		Range of concentrations in the main portal vein tributaries
	In tumour draining vein	In main portal vein tributary at tumour level	
	µU/ml	µU/ml	µU/ml
Insulinomas			
1	–	865	93–260
2	600	300	13– 58
3*	1 130	45	11–165
4*	745	14	11– 68
5	6 200	179	14– 78
6	974	95	95–230
	pg/ml	pg/ml	pg/ml
Glucagonomas			
1	[illegible]4 000	2 900	1 370–2 400
2	10 000	800	600–1 750
3	10 650	[illegible]	856–[illegible] 213

* B-cell hyperplasia

Postoperative analyses proved that the tumour secernated somatostatin and localization of the tumour by arteriovenous somatostatin concentration differences was possible One islet cell tumour could not be localized by the hormones analysed but could be classified as a D_1 cell tumour by electron microscopy

Postoperative examinations Six patients in whom resection of the pancreas had been performed were catheterized postoperatively 3 of them twice

In 3 patients in whom adenomas had been enucleated postoperative triple catheterization was performed in one of them twice

In one patient with Zollinger–Ellison syndrome recurrence was suggested which was confirmed operatively A recurrence was suggested also in one patient operated upon for a glucagonoma but the patient refused further investigations and operation

Value of selective catheterization Three insulin producing islet cell tumours could have been located by blood sampling in the main tributaries of the portal vein system (Table) The islet cell hyperplasia had not been located without selective catheterization of pancreatic veins In one patient with glucagonoma the location of the tumour could only have been suggested and one had been missed without

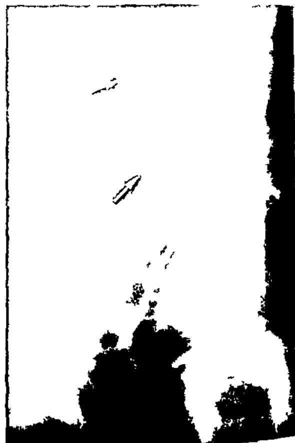


Fig 8 Insulinoma of the head of the pancreas The hormone analyses could not locate the tumour Injection into ant sup ver reveals a venous connection between the head of the pancreas and the left lobe of the liver (→)

selective examination In one case no sample was withdrawn outside the tumour draining vein

Complications

In one patient abdominal pain and fever followed accessory puncture of the gallbladder The condition was normalized after 2 days In one patient a cm×12 cm hematoma in the right lobe of the liver developed after percutaneous transhepatic portography No specific treatment was needed

Discussion

Angiography is regarded as the method of choice for localization of islet cell tumours of the pancreas The reported accuracy in localization of insulinomas varies widely In a review of 170 cases of the literature STEFANINI et coll (1974) found a success rate of 66 per cent All islet cell tumours producing hormones known today have the same angiographic appearance The accuracy of angiography in locali



a



b

Fig. 9 Phlebographic anatomy can be identified during operation a) Phlebography of the head Injection into ant sup vein Colon vein (↔) ant sup branches (→) b) Veins of the head of the pancreas after dissection in situ Colon vein (↔) ant sup branches (→)

...ation of other tumours than insulin producing is not known as the number of reported cases is too small

Gastrinomas are often multiple and in the present series it was not possible to demonstrate all the tumours in one patient by angiography Neither was it possible to locate multiple gastrinomas by portography and hormone analyses Generally elevated gastrin concentrations were certainly suggesting multiplicity of gastrin releasing tumours but could not locate these tumours Total gastrectomy has been the accepted method of treatment in patients with Zollinger–Ellison syndrome The recently introduced histamin H_2-receptor antagonists (STAGE et coll 1976 BONFILS et coll 1977) have raised new possibilities If an accurate preoperative localization of gastrinomas can be obtained extirpation of the tumours and resection of the antrum of the stomach and duodenum will be the therapy of choice In patients with multiple gastrinomas which cannot be located treatment with H_2-antagonists should be tried

All glucagon producing tumours could be demonstrated by angiography In one patient with a glucagonoma of the head of the pancreas which even released insulin and serotonin high insulin concentrations were found in a vein of the tail These concentrations were 7 to 10 times higher than the insulin concentration of the main portal vein tributaries strongly indicating that an adenoma or B cell hyperplasia was present in the tail even if it was not demonstrated by immunocytochemistry

In one patient with an insulinoma of the head of the pancreas neither angiography nor hormone analyses could locate the tumour The failure of triple catheterization was due to an unusual anatomy of the veins of the head of the pancreas Injection of the post sup pancreaticoduodenal vein as well as the ant sup vein revealed a vein of the hepatoduodenal ligament between the head of the pancreas and the hilum of the liver probably draining a cranial part of the head directly to the portal vein branches of the left lobe of the liver (Fig 8)

Very small islet cell tumours and islet cell hyperplasia cannot be located by angiography In these cases selective catheterization of the pancreatic veins was necessary for localization of the lesions as the hormone concentrations in the splenic vein at the level of inflow of the draining vein were not elevated as compared to other samples

The accuracy of both angiography and triple catheterization was in the present series higher than of one method alone If possible both angiography and triple catheterization should be performed for preoperative localization of endocrine pancreatic

tumours The rate of angiographic false positive diagnoses of 60 reported investigations for suggested insulinomas was 11 per cent (KOROBKIN et coll 1971) In one case of the present material an accessory spleen was demonstrated at angiography Angiographic differentiation between an accessory spleen and an islet cell tumour is sometimes impossible

In patients with hyperinsulinism or glucagonoma syndrome with positive angiographic findings however only in one of six cases unexpected high insulin concentrations were found at another location than the angiographically demonstrated tumour The number of patients is small and it is possible that multiple endocrine disturbances in the same pancreas are more common

If blood sampling for hormone assay is performed the examination should include selective catheterization of the pancreatic veins especially if angiography did not locate a tumour Islet cell hyperplasia and even adenomas can be missed if only sampling at different levels in the main tributaries of the portal vein is performed (Table)

Furthermore there was no evidence of increased complications if selective examinations of the pancreatic veins were performed The complication risk was obviously correlated to the percutaneous puncture of the portal vein not to selective catheterization of the veins

Phlebography of the pancreatic veins was necessary for proper documentation of the places of blood sampling Knowledge of the individual venous anatomy was important for evaluating hormone concentration differences By dissection of the veins during operation (Fig 9) according to the phlebographic anatomy and the hormone concentrations of the sampled blood an occult adenoma and islet cell hyperplasias were found

Selective catheterization of the pancreatic veins in an extensive manner as aimed at in blood sampling for hormone assay seems only possible using the percutaneous transhepatic approach to the portal vein The transumbilical approach implies a course with several curves and angles which makes selective catheterization of veins of the body and tail hazardous and difficult

SUMMARY

Based on 45 examinations the technique of selective catheterization of the pancreatic veins for blood sampling using the percutaneous transhepatic approach to the portal vein is described The results are compared with the angiographic findings in 16 patients with islet cell tumours and islet cell hyperplasia

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OM THE DEPARTMENTS OF RADIOLOGY LAZZAROTTO S HOSPITAL PORTO ALEGRE HOSPITAL SIRIO BANES SAO PAULO BRAZIL RIKSHOSPITALET OSLO NORWAY HOSPITAL SANTA IZABEL BLUMENAU BRAZIL AND COOPER MEDICAL CENTER CAMDEN U S A

ANGIOGRAPHY IN CYSTADENOMA AND CYSTADENOCARCINOMA OF THE PANCREAS

R UFLACKER N M AMARAL S LIMA T AAKHUS
E PEREIRA and K KURODA

Primary cystic neoplasms arising from the pan eatic acinar epithelium may be benign (cyst denoma) or malignant (cystadenocarcinoma) hey are usually single and often produce no mptoms Their clinical presentation is similar and e differential diagnosis between the two forms is ifficult Histologic typing is a further difficulty in ese cases

The angiographic findings in 2 cases of pancreatic ystadenomas have been described as early as 1957 PYRAH & COWIE) although specific angiographic atures have not been described until later (SWAN ON 1963 PRESSMAN et coll 1973) These tumours re rare and few reports on their angiographic ap- earances are available Therefore cases from sev ral institutions were collected to obtain a larger ample for analysis

Material and Methods

The material consisted of 9 females 16 to 57 years of age with surgically proved cystic neoplasms of he pancreas which had been previously examined with angiography Five of the tumours were clas ified as benign cystadenomas and the other 4 as malignant cystadenocarcinomas

Three of the cystadenomas arose from the tail one from the body and one from the head of the pancreas In 3 cases an upper abdominal mass was palpable Pain was present in all patients but one No calcifications were demonstrated within the growths The tumours were large ranging from 4 to 10 cm

Two of the cystadenocarcinomas were located in the head of the pancreas and the other 2 in the tail Their size varied between 10 and 18 cm and an abdominal mass was palpable in all patients jaundice was present in 2 No calcifications were found within the tumours

Selective catheterization of the celiac splenic superior mesenteric and inferior mesenteric arteries was performed after percutaneous puncture of the femoral artery Superselective catheterization was occasionally carried out and inferior cavography performed in one case

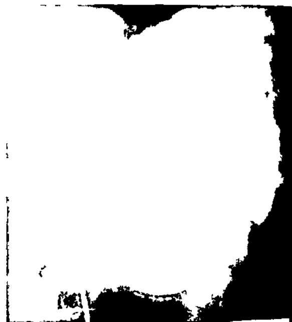
Results

Cystadenoma Four of the 5 cystadenomas were demonstrated at selective angiography Small capillary vessels and pathologic vessels were present in all cases Three masses were highly vascularized well delineated and smooth and with arteriovenous shunting and early venous filling (Figs 1 2) One tumour was poorly vascularized with tiny irregular vessels and faint contrast accumulation In the case without pain no tumour was demonstrated at angiography but a splenic artery aneurysm was present this tumour was found at operation

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a



b

Fig 1 Large pancreatic cystadenoma in the tail displacing the splenic artery and vein Rich vascularization of the tumour (a) as well as accumulation of contrast medium (b)



a



b

Fig 2 Richly vascularized cystadenoma causing partial occlusion of the splenic vein (→) with venous collateral

All cystadenomas but one were supplied by branches of the splenic artery and were clearly demonstrated as being of pancreatic origin at angiography One cystadenoma was mainly supplied by branches of the superior mesenteric artery (middle colic artery and transverse pancreatic artery) and only tiny vessels came from the splenic artery Collateral venous circulation existed in one of the cystadenomas probably secondary to compression the splenic vein which was only partially fi (Fig 2)

Microscopically small cysts lined by typical flat cuboidal epithelium containing serous or mucu fluid were demonstrated but no papillary proj tions

Cystadenocarcinoma All four cystadeno

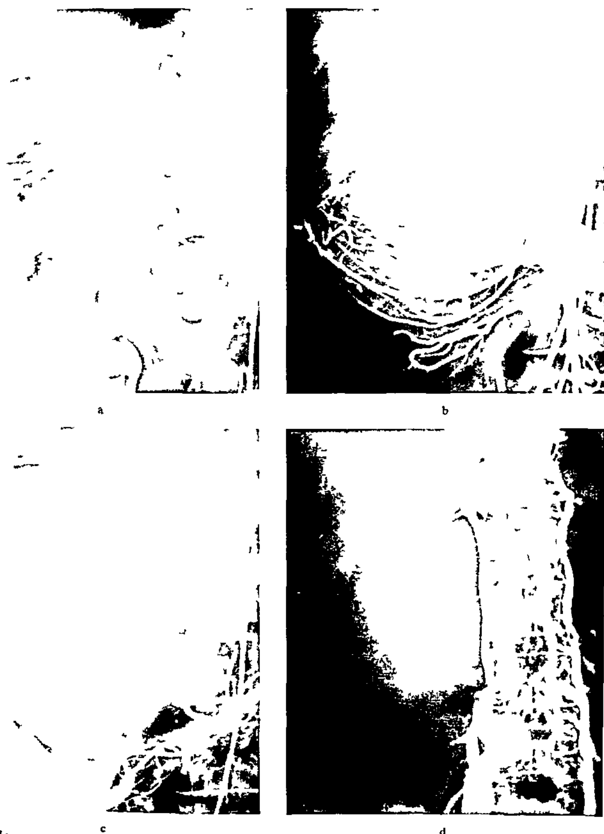


Fig 3 Large cystadenocarcinoma of the pancreatic head a) Stenosis of the hepatic artery and displacement of the vessels b) Tumour is partially supplied from arteries arising from the superior mesenteric artery c) The capillary phase is followed by arteriovenous shunting d) Total occlusion of inferior vena cava



a



b



c

Fig 4 Pancreatic tail cystadenocarcinoma a) Rich vascularization and tumour vessels Splenic artery aneurysm (↔) b) Infiltration of the left colic artery (↔) c) Occlusion of the inferior mesenteric vein (→)

nomas were demonstrated at angiography The gest tumour was hypovascular and the other 3 re richly vascularized Neoplastic vessels were esent in all and contrast accumulation within the asses was evident A large cavity within one of the oplasms produced a filling defect in the paren ymatous phase

The tumours located in the head of the pancreas oduced encroachment and infiltration of the ar nes of the liver and were supplied mainly by the stroduodenal artery Displacement of vessels and tenovenous shunting with early filling of veins and e portal system were observed in these cases One the tumours was also supplied by branches of the perior mesenteric artery (inferior pancreatico-uodenal artery) and inferior cavography dem nstrated total occlusion of the inferior vena cava nd wide collaterals through the vertebral venous ystem (Fig 3)

The neoplasms located in the tail of the pancreas roduced displacement of the splenic artery and ere supplied mainly by branches of this artery (Fig which was infiltrated in one case Arteriovenous hunting was evident with early venous filling and ultiple collaterals with obstruction of the splenic ein in another case One of these cases had a plenic artery aneurysm The tumour was supplied lso by the inferior mesenteric artery because of ncroachment and invasion of the left colic branch Fig 4) and the inferior mesenteric vein was infil rated

High cellularity and several mitoses were ob erved at microscopy Most of the tumours con ained only small cysts In 2 cases the tumours had multiple cysts and papillary formations

Discussion

The true incidence of cystadenomas and cyst adenocarcinomas is not well known (HAUKOHL & MELANED 1950) Little is understood about their histogenesis but they are accepted as being cystic neoplasms arising from the pancreatic acinar epithelium (PIPER et coll 1962) Evidence exists that cystadenocarcinomas can develop from cyst adenomas (BECKER et coll 1965 HAUKOHL & MELANED PIPER et coll PROBSTEIN & BLUMEN THAL 1960) Both tumours have the same gross aspect (SCALVINI 1960) and the definite diagnosis is established only at the microscopic examination It is not unusual to have areas of cystadenoma mixed with carcinomatous degeneration Gross papillary projections may be present in both tumours but are more likely to appear in cystadenocarcinomas Ba rium examination is of almost no value in the pre operative evaluation Angiography has proved to be of highest accuracy in their diagnosis and localiza tion

Cystadenoma According to BECKER et coll MOZAN in 1951 reported the first large review of cystadenomas and since then more than 250 cases have been reported (LEWIS & DORMANDY 1971) The tumours are known to be related to an increased risk of diabetes mellitus and SOLOWAY (1965) de scribed their association with numerous metabolic and endocrinologic abnormalities Cystadenomas almost exclusively occur in females with a predomi nance in a ratio 9 1 (BECKER et coll CULLEN et coll 1963 HAUKOHL & MELANED PIPER et coll) In the present series all the patients were females The majority of pancreatic cystadenomas occur be fore 50 years of age and even in youth (PRESSMAN et coll) which also was the case in the present series (ages between 16 and 57 years) A variety of sizes is described for cystadenomas from very small to huge masses but most of the tumours are between 6 and 10 cm in diameter (BECKER et coll) the size of the tumours in the present 5 cases was between this range The tail of the pancreas is predominantly involved in about two thirds of the cases (GAL LART ESQUERDO 1953 PIPER et coll BECKER et coll) In the present series 3 tumours were located in the tail and one in the body and head of the pancreas respectively Few tumours have been de scribed to contain calcifications (HAUKOHL & MELANED) in the present series no case had calcific deposits

Several angiographic findings have been de scribed (PYRAH & COWIE BIEBER & ALBO 1963 SWANSON GLENN et coll 1964 BANG 1965 RAN NINGER & SALDINO 1966 ABRAMS et coll 1967 PRESSMAN et coll REUTER & REDMAN 1977) in cluding displacement of major vessels presence of large feeding arteries accumulation of contrast me dium within the tumour associated with pooling of contrast medium and numerous pathologic vessels However few hypovascular tumours with large di mensions sparse neovascularity and wide dis placement of vessels have been described (ABRAMS et coll PRESSMAN et coll) Displacement and oc clusion of splenic and portal veins with presence of collaterals is also frequently found but in spite of the high incidence of collaterals only one report of

bleeding gastric varices was found in the literature (LEWIS & DORMANDY)

The differential diagnosis between cystadenoma and non functioning islet cell adenoma may be difficult (REUTER & REDMAN) However hypervascular cystadenomas are more likely to have severe arteriovenous shunting higher flow and increased venous return Other pancreatic lesions should not present such difficulty in differential diagnosis with hypervascular cystadenomas

In the present series 3 cystadenomas were easily diagnosed at angiography They were richly vascularized tumours with neovascularity contrast accumulation and arteriovenous shunting with early venous filling One mass was not detected at angiography but the films were of poor quality Another tumour was hypovascular but neovascularity was present and a faint contrast accumulation occurred (Fig 4) As in ordinary pancreatic adenocarcinoma the pancreatic origin of the growths could be determined in all cases

Cystadenocarcinoma According to CULLEN et coll KAUFMANN (1911) reported the first case of cystadenocarcinoma These tumours are more rare and no more than 70 cases have appeared in the literature (BECKER et coll CORNES & AZZOPARDI 1959 CULLEN et coll) Pancreatic cystadenocarcinomas usually affect young females and are said to be half as common as benign cystadenomas Frequently they grow slowly with a tendency to remain localized even when attaining a large size (SCALVINI BECKER et coll) The features of the present 4 cases agree with the literature except in their distribution only 2 cases were located in the tail

Few reports on the angiographic appearances in these tumours are available (ABRAMS et coll RÖSCH & BRET 1965 SUZUKI et coll 1971) They are usually described as large masses with wide displacement of arteries and hypervascularity with irregular and truncated vessels and infiltration of feeding arteries Recently computer tomography and gray scale ultrasound of pancreatic cystadenocarcinoma has been reported (CARROL & SAMPLE 1978) The appearances are not specific though compatible with those of cystic tumours

At angiography all the present tumours except one were hypervascularized masses with dense accumulation of contrast medium and marked neovascularity Infiltration of feeding arteries associated with venous occlusion or marked compression of large branches were frequently found (Figs 3 4) Arteriovenous communications existed Only one large cystic cavity was observed si ing that cystic cavities are usually small an not demonstrated at angiography In 2 cases an atheromatous aneurysm of the splenic arte demonstrated Such a combination has been ously reported only once (SUZUKI et coll)

Conclusions

Angiography not only plays a decisive rol demonstration of the origin of the tumour its and vascularity but may also permit the diffe tion of a benign from a malignant lesion Rich larity and arteriovenous shunts occur in be well as in malignant tumours but the prese arterial and venous infiltration and encroa indicates malignancy Cystadenocarcinoma invade adjacent structures and simulate he gastrointestinal neoplasms Large cystic seem to be rare A tendency exists for ma tumours to be larger than benign ones A chance for association of splenic artery ane with these neoplasms may be present

SUMMARY

The angiographic findings in 9 surgically prove of primary cystic neoplasms of the pancreas are r Angiography demonstrates the extent and origin tumour and permits in many cases a differential tween benign and malignant lesions

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NONINVASIVE MEASUREMENT OF FETAL AND NEONATAL BLOOD FLOW

M H REID R S MACKAY and B M T LANTZ

Doppler ultrasound is widely used to assess flow in major extremity and carotid arteries but quantitative data are difficult to obtain unless the vessel lumen diameter orientation of the vessel with respect to the ultrasound beam and the fluid velocity profile are uniquely known This report discusses observations of fetal and newborn blood flows using a doppler instrument which overcomes many of the problems mentioned

Materials and Methods

A new technique employing continuous wave doppler ultrasound with doppler frequency discrimination has been reported to give excellent correlation with dye dilution and thermodilution measurements of cardiac output in animals and adult humans (correlation coefficient in dogs 0 92 MACKAY & HECHTMAN 1975 REID et coll 1980) The advantage of this particular instrument is its ability to discriminate between advancing and receding flow and selectively measure that velocity of blood in the aortic arch which is parallel to the ultrasound beam Descriptions of the instrument and results obtained in adults are reported elsewhere (MACKAY 1972 REID et coll) As part of a larger evaluation program this doppler instrument was used to measure the aortic arch flow in 6 fetuses in normal pregnancies and 2 normal newborns and the umbilical flow in ? fetuses

For clarity a brief description of the doppler instrument is given A continuous wave 2 0 MHz doppler signal is generated and the return signal is shifted up in frequency for flow advancing toward the transducer or shifted down in frequency for flow receding away from the transducer Each of these possibilities is electronically separated by appropriate bandpass crystal filters centered above and below the center frequency of 2 0 MHz Thus advancing and receding flow can be differentiated Next the doppler return signal is mixed with the 2 0 MHz standard and an audio signal ranging from 300 to 3 300 Hz is produced This is passed through a set of ten bandpass filters and an electronic switching network which results in an output voltage proportional to the instantaneous maximum doppler frequency shift at each moment of time The result is that the output signal recorded on a chart recorder represents the instantaneous maximum flow velocity within the 2 0 cm diameter doppler ultrasound beam This is the key to the success of this instrument because the measured flow obtained by ensonifying a tortuous artery is therefore measured at a position where the artery is most nearly parallel to the doppler beam Therefore the usual problem of aligning the vessel ultrasound beam is not critical For example a 25 error in alignment of the ultrasound beam and measured vessel results in only a 10 per cent under-estimate of flow

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Conventional B scan ultrasound was employed to image the aortic arch and descending arch of the fetuses during routine obstetric ultrasound examination Care was taken to assess the position and orientation of the fetus and fetal aortic arch Only those fetuses which could be scanned from a fetal lateral approach were examined because of the necessity of directing the doppler ultrasound beam in a near axial direction to the transverse portion of the thoracic aortic arch (Fig 1) After obtaining an adequate B scan image of the thoracic arch for measurement and localization the doppler ultrasound probe (2 0 cm diameter 0 5 cm thick disc) was placed between the B scanner transducer and the maternal abdomen and proper doppler probe positioning obtained by reference to the B scanner stored image This is easily done by generating calibration scale dots on the B scanner and noting their position with respect to the stored image of the fetal arch The B scan transducer was then removed and a doppler measurement made

Visual (chart recorder) and audible observations of the doppler signal simplified the ensonification of the fetal aortic arch Heart wall and cardiac valve velocity sounds were significantly unique to allow easy differentiation from that of flow velocity in the fetal arch Heart movement was characteristically lower in frequency (i e low velocity motion) than arch blood flow Cardiac valves had a recognizable crisp snap to their audible character This simplified the fine adjustment of the doppler transducer and the measurement of fetal aortic flow could be obtained quite rapidly in a few minutes Gestational ages ranged from 30 5 weeks to term

Umbilical cord artery flow was easily obtained by ensonifying a region of the cord where at least some of the cord was parallel to the doppler ultrasound beam This is an easy requirement to satisfy because the umbilical cord is quite tortuous in its course A B scan image of the umbilical cord will often give a measurement of one of the umbilical artery diameters If this is not possible a measurement of the umbilical cord diameter can be used to estimate the umbilical artery size by reference to known umbilical anatomic measurements (Fig 2 REYNOLDS 1952)

A similar technique of aortic arch measurement was employed in two healthy newborn infants (female age 48 h weight 3 86 kg male age 72 h weight 3 96 kg) B scan images of the aortic arch were obtained by scanning directly through the thin cartilagenous sternum (Fig 3) The doppler probe appropriately placed near the suprasternal ...re receding flow in the aortic arch

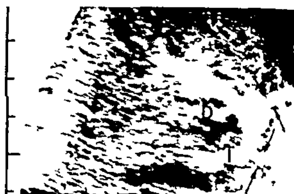
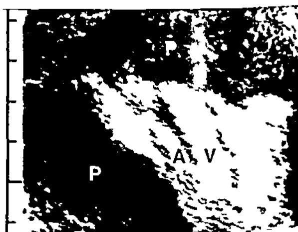
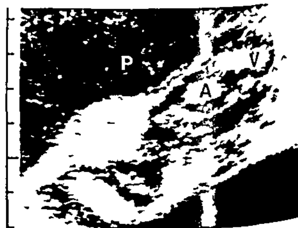


Fig 1 Aortic arch in a fetus Calibration marks spacing 1 0 cm Brachiocephalic artery (↦) Left subclavian artery (→) D ductus arteriosus I=aortic isthmus

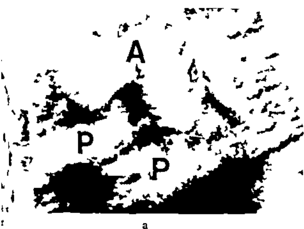


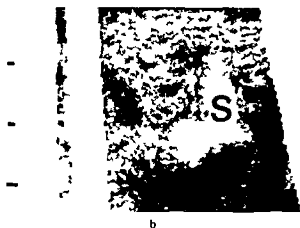
a



b

Fig 2 Umbilical cord in a fetus Calibration marks spacing 1 0 cm A=artery P=placenta V=vein





ıg 3 Aortıc arch ın a newborn a) Transverse scan parallel to aortıc arch b) Longıtudınal scan perpendıcular to aortıc arch Calıbratıon marks spacıng 1 0 cm A=aorta P=pulmonary artery S=left subclavıan artery

Results

The predıcted and measured blood flows ın the fetal transverse aortıc arch aortıc ısthmus and umbılıcal cord are summarızed ın the Table The posıtıon of the doppler measurement ın the aorta was largely a functıon of fetal posıtıon wıthın the maternal abdomen Fıg 1 ıs a representatıve B scan ımage of a fetal aortıc arch demonstratıng the aortıc ısthmus and transverse arch The aortıc arch lumen dıameter ıs obtaıned from these ımages Fetal weıghts were estımated from publıshed bıparıetal dıameter–gestatıonal age and weıght charts so that the data of the Table could be presented ın a standardızed form (ml/mın/kg WIENER et coll 1977) Except for Wınsberg s estımates of fetal left ventrıcular stroke volume the comparıson data from prevıous reports (Table) are derıved from measurements ın fetal lambs No comparable data ın undısturbed thırd trımester human fetuses are avaılable A few measurements have been reported for prevıable fetuses taken at hysterotomy ın early pregnancy (ASSALI et coll 1960)

Table

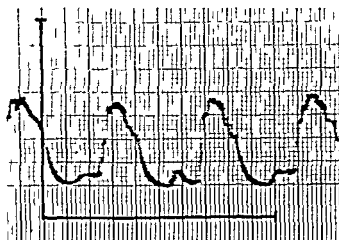
Fetal blood flow (ml/mın/kg)

	Transverse aortıc arch	Isthmus aortıc arch	Umbılıcal cord
WALSH & LIND (1978)	–105		
DAWES (1968)	120–159	1.0	180
MAHON et coll (1966)	–167		
ASSALI et coll (1960 1965)	– 97		110
RUDOLPH (1974)	45–135	45	200
WINSBERG (1972)	–163		
Doppler			
Case 1	126		
Case 2	92		128
Case 3	112		
Case 4	115		183
Case 5		60	
Case 6		45	

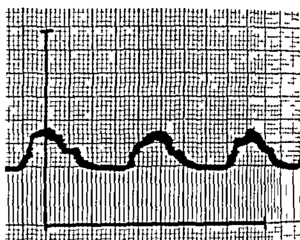
Assumes 15 ml/mın/kg coronary flow Range shown from ascendıng aortıc arch to ısthmus

Prevıable human fetuses 360 ml/mın/kg combıned left and rıght ventrıcular output estımate 170 ml/mın/kg left ventrıcular output

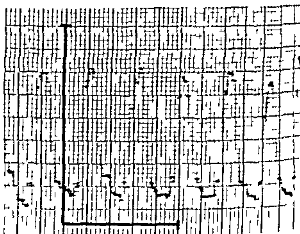
Comparıson data from end gestatıon fetal sheep



a



b



c

Fig 4 Blood velocity recordings Calibration abscissa—1 s ordinate—100 cm/s doppler flow velocity a) Fetus Transverse aortic arch b) Umbilical cord artery c) Newborn Descending aortic arch

Fig 2 illustrates the typical B scan appearance of the umbilical cord Umbilical artery lumen diameter can be measured from the image or an estimate of the arterial size can be made from the umbilical cord diameter and reference to published anatomic measurements of umbilical cord (REYNOLDS)

Similar flow measurements were obtained in two healthy newborn infants with descending aortic arch lumen diameters of 7 mm The calculated descending aortic arch blood flow was 160 ml/min/kg for the 48 hour-old female infant and 180 ml/min/kg for the 72 hour old male infant Allowing for 25 per cent of left ventricular output to the coronary and brachiocephalic vessels previously published values for neonatal cardiac output would indicate that descending aortic blood flow should be 150 ml/min/kg (RUDOLPH 1974) 120 to 190 ml/min/kg (WALSH & LIND 1978) 200 ml/min/kg (EMMANOUILIDES et coll 1970) Fig 4 illustrates representative doppler blood velocity recordings from fetal aortic arch umbilical cord and a newborn descending aortic arch

Discussion

The problem of ascertaining exactly the position of flow velocity measurement in the fetal aortic arch when the ductus arteriosus is functional is appreciated Reference to the expected anatomic vascular orientations of the fetal arch and the restricted active area of the ultrasound beam indicate that the flow within the ductus arteriosus should not interfere with arch velocity measurements using this particular doppler device Correlation with predicted results from examinations of fetal lambs is given in the Table and indicates close agreement with the doppler measurement data mentioned

Umbilical cord flow is obtained from doubling the flow values calculated for one umbilical artery It is not possible to measure each artery separately and

This flow calculation is thus a compromise and subject to many assumptions concerning umbilical artery sizes and flow distribution. Even with these disadvantages the measured values in the Table correlate well with expected umbilical blood flow.

Neonatal aortic blood flow was measured with the doppler ultrasound beam directed caudally from the suprasternal notch. Setting the instrument for receding flow and directing the beam toward the descending aortic arch will reject flow in the ascending arch, pulmonary artery, and brachiocephalic vessels and the perpendicularly oriented ductus arteriosus will not contribute to the flow measurement with this particular instrument. The measured aortic flow should then be near the junction of the ductus arteriosus with the aorta. The ductus arteriosus would be expected to be functionally closed within the first day of life (DAWES 1968).

The major error of this method of flow determination is related to uncertainties in measuring vessel lumen size at the site of the doppler observation. Flow is proportional to the doppler measured blood velocity and the cross sectional area of the vessel and therefore the square of the vessel lumen diameter. Ultrasonic fetal aortic measurements on the order of 7 mm are subject to at least a ±1 mm measurement error or approximately a ±30 per cent flow error. This error can be minimized by multiple B scans of the same area but it is unlikely that precision would improve much more than ±0.5 mm in fetal or neonatal aortic size determination.

Another issue of some concern is the assumed velocity profile across the aorta. Good experimental evidence exists to indicate that the velocity distribution is essentially constant across the aorta except immediately adjacent to the aortic valve (McDONALD 1974, FALSETTI et coll. 1972, LING et coll. 1968, ROCKWELL et coll. 1974). Thus the doppler measured velocity can be multiplied by the vessel cross sectional area to give the flow. Qualitative observations of flow using a range gated pulsed doppler system have been described (TAYLOR et coll. 1979). The advantage of the continuous wave doppler device described in this report is the doppler shift frequency analysis which automatically selects that velocity most parallel to the ultrasound beam. This is particularly useful for example in observations of umbilical cord flow where the vessels are quite tortuous and all that is necessary is to ensonify a cluster of the cord. Variations in the assumed velocity profile secondary to vessel bends have not been included in this analysis as it did not seem justified for the level of precision obtained. A parabolic velocity profile was assumed in the umbilical artery.

It should be noted that often the most clinically useful information is related to changes in blood flow over some hours or days. For this case the precision of the vessel diameter is immaterial provided the vessel size does not change during the course of the doppler observations. Thus changes in blood flow in a specified vessel may be noted with accuracy.

Conclusions

Doppler ultrasound blood flow observations in undisturbed human fetuses in the last trimester of pregnancy have been described. Comparison with expected values from examinations of fetal lambs implies reasonable accuracy. The clinical efficacy of these measurements in fetal distress, labor, congenital anomalies, etc. may be speculated upon and these and other applications are currently under investigation.

SUMMARY

A newly developed doppler ultrasound flow measuring instrument was applied to determination of aortic arch blood flow in 6 near term fetuses and 2 neonates and to umbilical cord flow in 2 fetuses. The method and results are presented and indicate good agreement between this noninvasive technique and expected values for aortic arch flow in human fetuses and neonates.

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EFFECT OF INTERPOSED SKIN AT DOPPLER FLOW ESTIMATION AT 5 AND 10 MHz

With a description of a calibration device

L. FORSBERG and T. OLIN

The Doppler effect was first described in the mid le of the nineteenth century by Doppler & Ballot They showed that the sound waves emitted from a moving source of sound have a higher frequency when the source is approaching the listener and a ower frequency when the sound emitter is leaving This effect has been used for medical purposes since 1959 when SATOMURA begun recording flow veloci y Sound waves reflected from moving particles are nfluenced in a similar mode When a sound beam is eflected from particles moving towards the emitter the reflected frequency is higher than the emitted one when it is reflected from particles moving away from the emitter the frequency is lower This change in frequency is proportional to the flow velocity and called the Doppler shift or the Doppler frequency Quantitative flow measurements using Doppler technique have been carried out with fairly simple equipment by for instance STEGALL et coll (1966) BERNSTEIN et coll (1970) and LO GERFO & CORSON (1976) all reporting very promising results

The equipment used was a continuous wave directional Doppler (Parks 806) with calibration facilities The sound is emitted and received from piezo-electric crystals 2 mm×5 mm each on top of a pencil probe The frequency of the ultrasound emitted from the probe was 10 MHz (9 5 MHz) For measurements with 5 MHz a Parks 906 was used This apparatus has no calibration facility installed why calibration had to be made before starting this investigation

The Doppler equipments mostly employed in flow examinations are using ultrasound in the frequency of 5 to 10 MHz The change in frequency is proportional to the velocity of flow in the structure examined and it is also proportional to the emitted frequency This means that a higher Doppler frequency is obtained when examining a vessel with high flow velocity using a high frequency The resolution of measurements is higher using a high ultrasound frequency increasing proportionally On the other hand the attenuation of ultrasound in tissues increases with the frequency This means that only superficial vessels can be examined with a 10 MHz probe

The Doppler equation used for quantitative flow velocity measurements is as follows

$$\Delta F = F_e - F_r = F_e - F_e \times \frac{c - v \cos a_1}{c + v \cos a}$$

where

ΔF = Doppler frequency (kHz)
F_e = emitted frequency (kHz)
F_r = received frequency (kHz)
c = velocity of ultrasound in blood $1\ 56 \times 10^5$ cm/s
v = velocity of flow cm/s
a_1 and a_2 = angles between emitted and received sound beam and blood vessel
a = angle between pencil probe and blood vessel

Due to the construction of the pencil probe

$$a = \frac{a_1 + a_2}{2}$$

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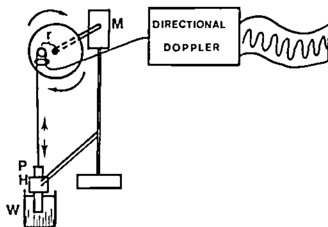


Fig 1

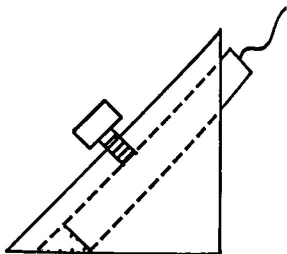


Fig 2

Fig 1 Calibrator designed for the experiments with 5 MHz Doppler equipment M = motor r = distance from peg to centre of the rotating wheel P = pencil probe H = holder W = glass of water

Fig 2 Plastic holder with a metallic screw to fasten the probe in the slide

Fig 3 Experimental design A = plastic bag containing human blood B = latex tubing C = jar for collections D = measuring glass E = Doppler probe F–G = Doppler apparatus and poly graph H = stop-watch J = clamp K = calibrator L = contact gel

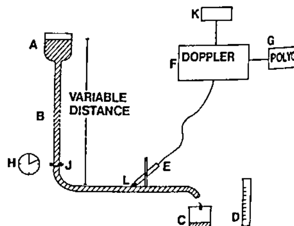


Fig 3

When $v \ll c$ this equation may be approximated by

$$F = \frac{2 F_e v \cos a}{c}$$

which can also be written

$$v = \frac{\Delta F \times c}{2 F_e \cos a}$$

The 5 MHz equipment Parks 906 had no calibrator which is necessary for quantitative measurements Therefore an apparatus (Fig 1) was designed for calibration It was constructed of a synchronized motor making a rotating wheel move a full circle per second On this wheel the cable of the probe could be attached at different distances from the centre of the wheel The probe was then guided by a slide allowing it to move perpendicularly to create idealized to and fro movements The probe was placed with the transducer in a glass of water The apparatus gave peculiar recordings until the bottom of the glass was covered with a soft non reflecting material The movements of the probe in the water were thus standardized and calibration procedures could start The maximum velocity of the probe is the same as the velocity of the peg around the centre of the wheel i e $2\pi \times$ the distance in cm between the peg and the centre of the wheel per second First the 10 MHz probe was used This Doppler apparatus was known to give correct information at examination of low velocities why the apparatus was used giving maximum velocities of 8 to 11 cm/s The polygraph was calibrated with the 1000 Hz generator and then fixed in one position to give comparable readings Velocity measurements were then performed with both 10 and 5 MHz (9 5 and 5 3 MHz) This procedure gave a calibration consta that could be used at all examinations after hav g

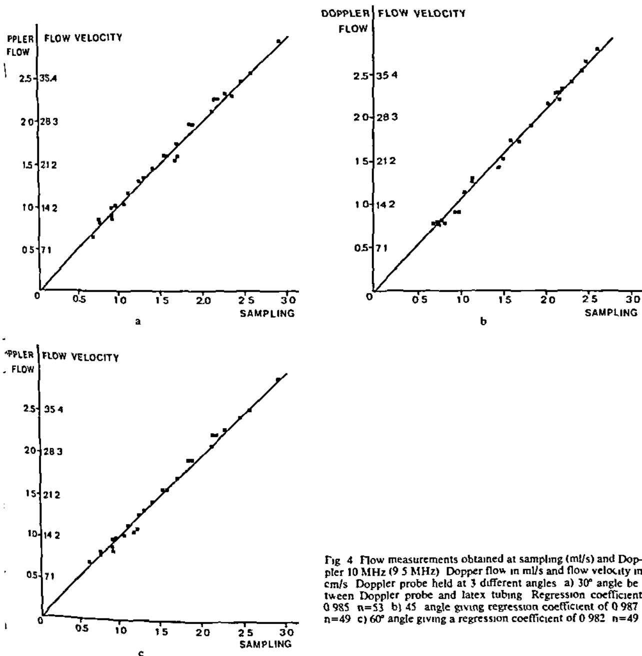
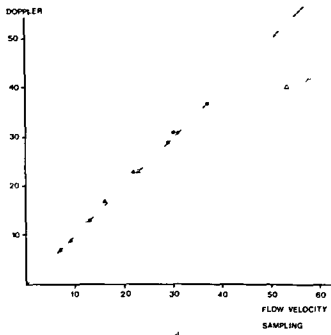


Fig 4 Flow measurements obtained at sampling (ml/s) and Doppler 10 MHz (9 5 MHz) Dopper flow in ml/s and flow velocity in cm/s Doppler probe held at 3 different angles a) 30° angle between Doppler probe and latex tubing Regression coefficient 0 985 n=53 b) 45 angle giving regression coefficient of 0 987 n=49 c) 60° angle giving a regression coefficient of 0 982 n=49

the polygraph calibrated against the 1000 Hz generator or directly against the calibrator

The influence on the flow measurement obtained by holding the 9 5 MHz Doppler probe at different angles (30° 45 and 60°) to the vessel (latex tubing) was examined as were the effects of interposed skin between the probe of 10 MHz and 5 MHz and the vessel A plastic holder was designed in order to obtain reproducible and exact angles (Fig 2)

The probe used in these experiments was a pencil shaped probe with the crystals placed at its end The experimental design is illustrated in Fig 3 A continuous flow of blood was obtained using a plastic bag (A) connected to a latex tubing with a diameter of 3 mm (B) where the bag could be fixed at different levels above the table creating flows of varying velocities The flow was started by opening a clamp (J) Timed collections were performed simultaneously with the Doppler measurement (L) represents the transmission medium (E) the Doppler probe (K) stands for the oscillator used for calibration of the apparatus (G) is the polygraph (Mingograf 800 Siemens Elema) The Doppler apparatus (F) used in the experiments was a Parks 806



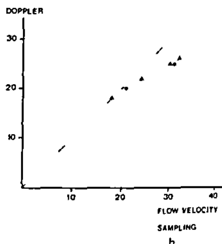


Fig 5 Flow measurements at sampling and Doppler 10 MHz (9 5 MHz) with interposed skin Flow velocity in cm/s a) Direct coupling with gel (●) Interposed skin of rabbit (Δ) A 20 per cent loss in the area of 30 cm/s or more b) Very stretched (▲) and moderately stretched (●) human skin interposed Extr[illegible] human skin (Δ) Also here a 20 per cent loss at about 30 [illegible] more

Directional Doppler Before every examination it was calibrated by connecting an oscillator with a known frequency (1 kHz) to the towards and away output sta[illegible]s

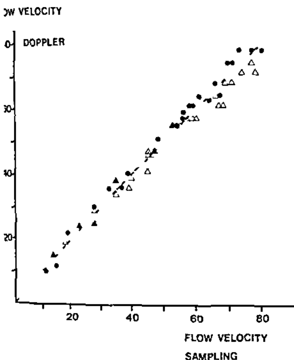
The blood used was discarded from the blood bank It was heparinized and mixed gently before the experiments started At this time blood hae matocrit was measured and found to be 41 and 44 per cent respectively The temperature of the blood was 10° to 15 C during the examinations which were performed in a room holding a temperature of 22 to 25°C True blood flow was measured by collecting the blood for a period of 30 to 60 seconds The cross sectional area of the latex tubing was 0 071 cm² Multiplication of this area by the values of linear flow velocity registered by the Doppler apparatus gave Doppler determinations of volumetric flow rate for comparison with the flow rate measured directly

The influence of different tubing materials was also analysed Polyethylene catheters were tried but could not be used since only irrelevant noise was registered probably due to absorption and reflection of the ultrasound waves The tubing used in the rest of the experiments was made of latex rubber with very few disturbing noises The influence of the angle between probe and vessel was also examined before proceeding with interposed skin The [illegible] between the probe and the vessel was made const[illegible] by triangular plastic holders for the probe (Fig [illegible]

Comparison between measurements of flow [illegible] milk instead of blood showed no difference in [illegible]mation obtained with Doppler which also was found by STEGALL et coll When analysing the effect of interposed skin holding 25 C (simple attenuation of ultrasound increases at lower temperatures) blood was used in the experiments where human skin was used and milk where skin from rats was used Sk[illegible] from rats turned out to have the same qualities as human skin when shaved and placed over the [illegible] tubing with the hairy side on the tubing after cover ing it with gel

Results

The effect of the angle between the 10 MHz probe and the vessel was correctly adjusted for by [illegible] formula for Doppler measurement of flow veloc[illegible] (Fig 4) The flow estimations were very close to th[illegible] expected ones obtained by sampling Measurements of flow were carried out up to velocities just over [illegible] cm/s The examinations concerning the effect of interposed skin were with 10 MHz carried o[illegible] expected flow velocities over 60 cm/s with the probe



ig 6 Flow measurements at Doppler 5 MHz (5 3 MHz) and at impling Flow velocity in cm/s Direct coupling between probe nd skin (●) Interposed skin (Δ)

fixed in a 45 angle to the vessel Fig 5 shows that he Doppler technique gives about 20 per cent too ow values with interposed skin when flow velocity s higher than about 30 to 35 cm/s It also shows that Doppler signals obtained with direct contact between probe and tubing are tending to be too low when examining flow velocities of more than about 40 cm/s Thus skin exerts a definite influence on the Doppler signal obtained with a 10 MHz probe especially when higher flow velocities are measured The results obtained with 5 MHz appear in Fig 6 where a good correlation is found up to velocities of at least 80 cm/s The interposed skin had a minimum damping effect on measurements at high flow velocities

Discussion

The experiments show that the angle between the probe and the vessel is correctly adjusted for by the formula which was theoretically to be expected It also shows that Doppler estimations using 10 MHz were accurate up to flow velocities of at least 40 cm/s with direct coupling with gel between probe and latex tubing What is more interesting is the effect of skin between the 9 5 MHz probe and the vessel as well as the too low signal obtained measuring higher flow velocities ranging from about 40 cm/s and higher The results correspond well with those of BERNSTEIN et coll and LO GERFO & CORSON who obtained accurate estimations of flow with a 10 MHz Doppler equipment corresponding to flow velocities of 30 to 35 cm/s compared with electromagnetic flowmeters

Some kind of limitations in the 10 MHz Doppler apparatus itself seem to exist In the present experiments interposed skin resulted in too low flow estimations from 25 to 30 cm/s and higher The skin used was only about 1 mm thick Thicker skin or lax skin distorted the signal progressively more This phenomenon might be due to attenuation of higher frequencies in the interposed structures as pointed out by SEIPEL et coll It is known that the Doppler signal from a continuous wave apparatus is built up from multiple frequencies representing a mean flow velocity of the vessel examined The transverse cross section of the vessel must be totally insonated by the sound beam to give correct readings Attenuation of the higher frequencies might lead to a signal built up by proportionally more lower frequencies representing a flow of lower velocity than expected The conclusion of the findings must be that measurements performed with a 10 MHz probe are somewhat underestimated when examining high flow velocities or when trying to quantify flow percutaneously at places where interposed tissue is thick

These findings initiated experiments with 5 MHz Doppler equipment After getting a calibrator constructed it was possible to use also this apparatus at quantitative flow measurements

Using a 5 instead of a 10 MHz probe is supposed theoretically to give a somewhat less distinct Doppler signal due to the lower Doppler frequency received at identical flow velocities However it seems to be of less importance compared with the better penetration abilities The apparatus itself (Parks 906) is giving a more correct signal at higher flow velocities than did the 10 MHz apparatus (Parks 806) The effect of the interposed skin seems to be near to negligible This means that percutaneous quantitative Doppler measurements of flow ought to be carried out with 5 MHz equipment in order to get best possible measurements especially when examining deeper lying vessels When having a calibrator that can be used on any Doppler apparatus it is possile to use a fairly simple and not too

expensive Doppler equipment for non invasive quantitative measurements

SUMMARY

Flow measurements with high ultrasound frequencies (Doppler technique) can be used at quantitative estimations of flow A calibrator for Doppler equipments is presented The effect of skin as interposed material with 10 MHz and 5 MHz is discussed as are limitations in the apparatus itself especially when using 10 MHz ultrasound

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FROM THE DEPARTMENTS OF SURGERY AND DIAGNOSTIC RADIOLOGY AKADEMISKA SJUKHUSET S 750 14 UPPSALA SWEDEN

DIAGNOSIS OF ABDOMINAL AORTIC ANEURYSMS BY AORTOGRAPHY COMPUTER TOMOGRAPHY AND ULTRASOUND

I ERIKSSON A HEMMINGSSON and P G LINDGREN

Clinical examination and aortography have been used for many decades in the diagnosis of abdominal aortic aneurysms However the reliability of diagnosis by palpation has been claimed to vary considerably according to the experience of the clinician Recently clinical examination was reported to give exact diagnosis in 90 per cent and aortography in 93 per cent (GORDON SMITH et coll 1978) The development of modern ultrasound has resulted in an increasing rate of diagnostic reliability (SEGAL et coll 1966 NUSBAUM et coll 1971 WINSBERG et coll 1974) which has been reported to be as high as 98 per cent (GOMES et coll 1978) Recent experiences with CT have shown that abdominal aortic aneurysms and intra aneurysmal thrombi can be diagnosed very accurately by this method in particular after contrast enhancement (GOMES 1977)

Exact preoperative determination of the upper limit of the aneurysm and its relationship to the renal arteries is of the utmost importance in planning the surgical procedure Information about the renal arteries obtained by ultrasound has been uncertain in many cases (HAAGA & REICH 1978) On the other hand aortography has clear disadvantages in being an invasive method afflicted with some adverse effects Therefore it was considered of value to compare the reliability of aortography and the non invasive methods ultrasound and CT in the diagnosis of abdominal aortic aneurysm and the determination of the relation between the aneurysm and the renal arteries

Material and Methods

Seventy-one consecutive patients were admitted for examination of a pulsating abdominal mass In patients with only slight indication of aneurysm ultrasound was first performed if nothing abnormal was found aortography was not carried out A total of 71 patients were examined by ultrasound and 20 each by CT and aortography (Table 1)

For aortography the catheter was introduced via the femoral or axillary arteries and films in antero posterior oblique and lateral projections were exposed Ultrasound was performed with a Sono Diagnost grey scale apparatus (Philips) and CT with an Ohio Nuclear Delta 50 FS apparatus (Scanning time 18 s) before and after intravenous injection of contrast medium (100 ml Conray Meglumin 280 mg I/ml)

The occurrence of an aortic aneurysm its upper limit and relation to the renal arteries and its lower limits were evaluated with each method In addition possible intraaneurysmal thrombus or retroperitoneal bleeding was recorded The number of renal arteries for each kidney was noted from the films

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a b



c

Fig 1 Aortography a) A p b) lateral projection Contrast filling of the lumbar arteries and inferior mesenteric artery but a straight left contour of the aorta below the renal arteries indicating a possible aneurysm c) CT after contrast enhancement. 6 cm wide aneurysmal aorta with intraluminal thrombus

Most patients with a diagnosis of abdominal aortic aneurysm were treated surgically and the operative findings were correlated to the observations at the preoperative examinations

Results

In 39 patients with slight indication of aortic aneurysm no abnormality was found at ultrasound (Table 1) The clinical course in these patients revealed that the abdominal discomfort was due to

Table 1

Number of examinations

	Aortography	Computer tomography	Ultrasound
Normal	6	6	39
Aneurysm	13	13	8
Tumor	1	1	
Unsuccessful			4
Total	20	20	51

Table 2

Number of patients with a correct and incorrect evaluation concerning the presence of an abdominal aortic aneurysm its extension and presence of an intraaneurysmal thrombus

	Aortography (20 cases)		Computer tomography (20 cases)		Ultrasound (71 cases)	
	Correct	Incorrect	Correct	Incorrect	Correct	Incorrect
Diagnosis	18	2	19	1	67	4
Cranial extension in relation to renal arteries	8	{4 {1	10	3	4	{10 {14
Caudal extension	10	3	11	2	28	
Intraaneurysmal thrombus	9	4	13		15	

calcified tumor or aneurysm
not examined

unsuccessful because of intestinal gas
not evaluable



Fig 2a

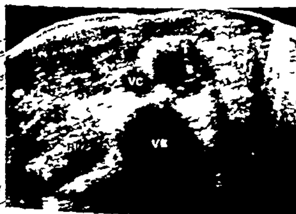


Fig 2b



Fig 3a



Fig 3b

Fig a) Longitudinal scan through the aorta The plane of transverse scan (b) is marked with vertical arrow b) Transverse scan A=aneurysm B=blood-containing part T=intraaneurysmal thrombus VB=vertebral body VC=vena cava RK right kidney

Fig 3 a) Aortography a p projection Aorta appears normal b) CT after contrast enhancement The partly calcified soft tissue mass cannot be distinguished from the aorta

other causes At clinical re examination no indication of aortic aneurysm remained and these patients were considered to have a normal abdominal aorta

A correct diagnosis was made in 18 patients at aortography (Table 2) In the remaining 2 patients with aneurysms the angiographic diagnosis was uncertain The inferior mesenteric artery and all lumbar arteries were contrast filled and no calcifications of the aneurysmal wall were present in either patient In these 2 patients the diagnosis was established at both ultrasound and CT (Figs 1 5) At operation these aneurysms were found to contain large organized thrombi on the inner aspect of the anterior wall below the level of the inferior mesenteric artery



a



b



c



d

Fig 4 a) Aortography a p projection CT at b) the center of the aneurysm c) the level of the left and d) of the right renal artery Leakage of contrast medium into the aneurysmal sac (a b) The aneurysm does not seem to involve the renal arteries (a) CT reveals that the aneurysm involves the aorta at the origin of both renal arteries (c d)

Ultrasound examination of the aorta was unsuccessful in 4 patients because of an abundance of intestinal gas which concealed the image and made evaluation impossible In the remaining 67 patients a correct diagnosis was obtained in all 28 with aneurysm (Table 2 Fig 2) and in the 39 without aneurysm i e 94 per cent correct diagnosis In 19 of 20 patients CT gave a correct diagnosis In the remaining patient a differentiation between an aneurysm and a calcified soft tissue tumor close to the aorta could not be made CT was performed only after intravenous contrast enhancement in this case Angiography revealed a normal aorta (Fig 3) and operation a calcified tumor

An intraaneurysmal thrombus was found in all cases with aneurysm examined by CT (Table 2) and in 15 (Fig 2) of the 28 cases with aneurysm examined by ultrasound The remaining 13 patients



a



b



c



d

g 5 a) Aortography a p projection Catheter cannot be passed enough to give contrast filling of the renal arteries Lum r arteries visible CT b) Intraluminal thrombus outside the contrast filled lumen of the aorta c) Renal arteries arise from a normal part of the aorta and d) can be distinguished from the renal vein Renal cysts on both sides

ad localized ectasias of the aorta In 4 cases in aaneurysmal thrombi were suggested at aortoraphy but not confirmed A diagnosis of aneurysm ad appeared probable on account of a straight aor c contour and no visible lumbar arteries In one atient a blood-conducting channel from the aortic umen through the organized thrombus and into the pace between the thrombus and the aortic wall was bserved both at aortography and at CT (Fig 4)

The extension of the aneurysms in the cranial irection was demonstrated most correctly by CT Table 2) By this method the upper limit of the neurysm and its relation to the renal arteries could e ascertained in all patients examined for that purose In 4 patients aortography did not disclose this elationship (Figs 4 and 5) In 10 patients the origins f these vessels were not examined by ultrasound In the remaining 18 patients with aneurysm the renal arteries and their distances from the upper limit of the aneurysm was demonstrated in 4 patients at ultrasound Extension of the aneurysm into the pelvic arteries was correctly revealed by all three methods in all patients in whom this was present

A retroperitoneal hematoma due to a ruptured aortic aneurysm was diagnosed in one patient at CT This was the only case of aneurysm rupture This patient was not examined by the other methods

Discussion

The results have demonstrated the value of ultrasound and computer tomography for diagnosis of abdominal aortic aneurysms The reliability of both these methods seems to be at least as good as that of

aortography Concealment of the image by intestinal gas is the most important obstacle to an ultrasound diagnosis while rare diseases close to the aorta may cause difficulties in CT

The upper limit of the aneurysm and its relation to the renal arteries was most correctly revealed by CT which in this respect was more reliable than aortography The origins of the renal arteries were visible in only a few cases at ultrasound but a refinement of the equipment especially with additional modern real time apparatus will probably improve this result

CT was also superior to aortography in demonstrating intraaneurysmal thrombi These were also observed with ultrasonography contrary to what has been reported previously (KARP & EKLÖF 1978)

Ultrasound and CT are non invasive methods without any risks which makes the examination comfortable and safe for the patient An additional advantage of ultrasound is its freedom from ionizing radiation Ultrasound should thus be the primary method of choice in patients with possible abdominal aortic aneurysm This is in accordance with the recommendations of KARP & EKLÖF If the diagnosis is not clearly established by this method or the extension of the aneurysm not clear CT is indicated It is evident that most cases of abdominal aortic aneurysm can be treated safely without preoperative aortography

SUMMARY

Aortography computer tomography and ultrasound were compared with respect to the diagnosis and evaluation of abdominal aortic aneurysms The results show that ultrasound should be the method of choice for diagnosis and that the extension of the aneurysm towards the renal arteries is best evaluated by computer tomography Aortography can thus be omitted in most cases

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THE DEPARTMENTS OF DIAGNOSTIC RADIOLOGY UROLOGY AND PATHOLOGY ULLEVAAL UNIVERSITY HOSPITAL OLSO NORWAY

TRANSCATHETER EMBOLIZATION OF THE RENAL ARTERY WITH BUCRYLATE IN RENAL CARCINOMA

ARNULF SKJENNALD BJØRN KLEVMARK and JAN TRYGVE STENWIG

urgical treatment of renal carcinoma is usually refrained from even if the tumour is infiltrating rounding tissues or distant metastases are pres

Even without such infiltration the removal of ge tumours can be technically difficult and com cated with heavy bleeding

Embolic occlusion of the renal artery in cases of cinoma results in infarction of the tumour and the lney The surgical procedure is then technically sier mainly due to less bleeding which also per ts an early admittance to the renal vein for ligation avoid discharge of tumour cells

Several agents have been used to obtain intra terial occlusion As results have not been entirely tisfactory the search for new and more suitable ents has continued The results using Bucrylate as e embolus inducing agent are now reported

Material and Method

The material consisted of 5 patients 3 men and women the youngest being 51 the oldest 73 years ean 63 6 The carcinoma was left sided in 3 and ght sided in 2 cases The largest tumour measured 9 cm × 16 cm on the films the smallest 10 cm × 7 m One patient had metastases in the liver and the ings another in the liver and the retroperitoneal pace The latter metastases were supplied mainly rom the gastro-duodenal artery No metastases or xtrarenal infiltration of the tumour were apparent n the other 3 patients

The renal arteries were catheterized from the right emoral artery using a Surgimed mat No 8 Cat No 160 catheter With a coaxial stop-cock a thin ner catheter was introduced through this cathe ter Bucrylate (Isobutyl 2 cyano-acrylat monomer) was injected through the inner catheter and the outer catheter continuously perfused with isotonic glucose The effects of the Bucrylate injections were controlled by abdominal aortography in all patients 15 min after the embolization (Fig 1)

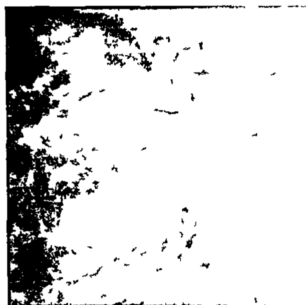
The age and sex of the patients size of the tu mour diameter of the renal arteries and the amount of Bucrylate injected appear in the Table

Results

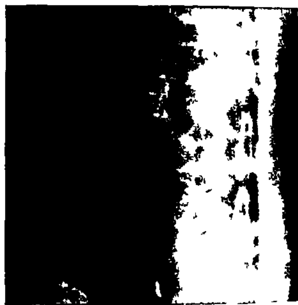
In 4 patients occlusion of the renal artery was obtained with 3 5 (Fig 2) 2 5 1 5 and 1 ml of Bucry late respectively (Table) In one patient a female aged 73 occlusion of the renal artery was incom plete following injection of 1 5 ml However as the patient complained of intense pain additional agent was not injected

Four patients were operated upon 14 22 30 and 38 days respectively after the intraarterial injec tions The kidneys were technically easy to remove because of only insignificant bleeding which made blood transfusions unnecessary The arteries were hard and gritty Coagulation necrosis of the in farcted areas including the renal carcinomas was present on microscopy The arteries were throm bosed to a varying extent (Fig 3 a) Tumour tissue outside the renal capsule including the renal vein was visible (Fig 3 b) The 73 year-old female with incomplete occlusion of the artery was not treated surgically

Submitted for publication 6 March 1979



a



b

Fig 1 a) Selective injection into right renal artery Large carcinoma b) Abdominal aortography 15 min after injection of 1 5 ml Bucrylate The artery is occluded

Adverse effects were pain for one to three days and fever Three patients had severe pain after the occlusion the other 2 patients complained of little or no pain In 2 of the patients fever of moderate to high degree occurred lasting from 5 to 9 days Pulmonary embolism was diagnosed in one patient 23 days after the embolization

Discussion

Arterial injection of autologous clots (CARMIGNANI et coll 1978) and other autologous material (ALMGÅRD et coll 1973 GOLD & GRACE 1975 TADAVARTHY et coll 1975 HIGGINS et coll 1977 BOOKSTEIN et coll 1978 CHANG et coll 1978) has resulted in initial occlusion of the vessel but recanalization often occurs BARTH et coll (1977) reported on long term follow up results of transcatheter embolization with autologous clots oxycel and gelfoam in domestic swine At 4 months recanalization was present in all cases Thus long lasting occlusions are probably difficult to achieve with these agents LUNDERQUIST et coll (1977) using gelfoam on the coronary gastric vein also recorded a high percentage of recanalization while VIAMONTE et coll (1977) did not observe recanalization in 10 similar patients also embolized with gelfoam The most commonly used agent for embolizing is gelfoam In the renal artery this agent is distributed even to the more peripheral branches of the vessel

Bucrylate rapidly undergoes polymerization and solidifies in a few seconds when mixed with blood It has been the most successful agent used to obtain embolization of the gastric coronary vein in patients

Table

Review of the material

Age (years)	Sex	Size of tumour (cm)	Diam of renal artery (mm)	Amount of bucrylate (ml)	Pain	Occlusion
51	M	19×16	12	3 5	Strong	Yes
70	M	16×16	10	1 5	No	Yes
73	F	10×17	5	1 5	Strong	No
73	F	11× 9	6	1 0	No	Yes
51	M	10× 7	10	2 5	Strong	Yes



a

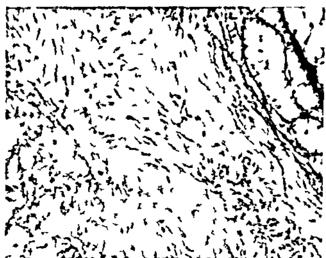


b

Fig. a) Large carcinoma in left kidney b) Aortography Complete occlusion of the renal artery after embolization with 3 5 ml Bucrylate



a



b

Fig. 3 a) Bucrylate with thrombotic material in renal arteries H & E × 30 b) Lower left area Necrotic tumour after artificial thrombosis Upper right area Viable tumour tissue outside the renal capsule H & E × 72

bleeding from esophageal varices due to portal hypertension (LUNDERQUIST et coll 1978) Bucrylate has also been used for control of other massive gastro-intestinal bleeding (GOLDMAN et coll 1978) CARMIGNANI et coll (1978) injected Bucrylate into the renal artery in 2 patients with renal carcinoma and obtained complete occlusion DOTTER et coll (1975) used Bucrylate in a patient with a heavy protein loosing glomerulonephritis After the embolization the patient became anuric and the protein loss stopped No recanalization occurred after embolization of the renal arteries in rats (CARMIGNANI et coll 1978) In contrast to gelfoam Bucrylate polymerizes and solidifies more centrally in the

artery and the effect is therefore more similar to that of a surgical ligation Embolic reflux is a possible complication Theoretically due to quick solidification this effect should be easier to avoid using Bucrylate However reflux would probably best be prevented by using a balloon catheter (GREENFIELD et coll 1978)

In the present series intraarterial injection of Bucrylate in 4 patients resulted in complete occlusion of the artery present also at the time of operation 14 to 38 days later In the fifth case with incomplete occlusion surgery was not performed

Postoperative examination of the removed kidneys showed the renal arteries totally filled with a plastic like material It seems reasonable that these arteries should be considered permanently occluded Large areas of necrosis and infarcted tumour tissue indicate that the tumours had effectively lost their arterial supply

Transcatheter embolization of the renal artery is not without complications In one of the present patients pulmonary embolism occurred It was diagnosed 23 days after the embolization but clinical signs indicated an earlier occurrence It is reasonable to suggest a connection between the pulmonary embolism and the occlusion procedure Because Bucrylate solidifies immediately after the injection there is little reason to believe that Bucrylate particles would have passed through the tumour A more obvious explanation is that sudden interruption of the arterial circulation decreased the flow in the renal vein with subsequent formation of clots This concept is supported by the delayed manifestation of the embolism

Occluding agents acting differently may cause pulmonary embolism because the injected particles can pass through the tumour CARMIGNANI et coll (1978) have shown that barium particles were able to pass the capillaries in rat kidneys and therefore could result in pulmonary embolism They found that gelfoam and Bucrylate did not pass the capillaries However theoretically all other embolizing agents than Bucrylate might pass through arteriovenous shunts in the tumour

Three patients experienced immediate strong ischemic flank pain which required the administration of potent analgetics The pain subsided over 1 to 3 days In one case intense pain led to interruption of the injection after a small volume (1 5 ml) when complete occlusion had not yet been obtained Two patients also had a rise in body temperature lasting from 5 to 9 days Flank pain and a rise in temperature have also been reported after embolization with gelfoam (GOLDSTEIN et coll 1975) their appearance seems to be independent of the agent used

The present series is small However in 4 patients the intraarterial injection of Bucrylate gave convincing results, both regarding immediate complete occlusion of the artery and its duration Bleeding at surgery was insignificant the operations were easy to perform and the renal vein could be isolated at an early stage The pathologic examination confirmed the radiologic and operative findings

Intraarterial embolization should not be used routinely in cases of renal carcinoma because inherent potential complications cannot be ignored The main indication for the procedure appears to be the very large highly vascularized carcinoma especially when located in the upper part of the kidney

SUMMARY

In 5 patients with large renal carcinomas Bucrylate was injected into the renal artery One to 3 5 ml Bucrylate were required to obtain occlusion of the arteries At operation 14 to 38 days later the arteries were still occluded One patient developed pulmonary embolism other complications were of less importance The main indication for the procedure is very large highly vascularized carcinomas in the upper part of the kidney Bucrylate seems to be a suitable embolus inducing agent

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RADIOGRAPHIC APPEARANCES IN CROHN S DISEASE

IV The new distal ileum after surgery

J HILDELL C LINDSTRÖM and A WENCKERT

Postoperative recurrence of Crohn s disease has attracted considerable interest in the clinical litera ure and has been analysed from several clinical and pathologic viewpoints (VAN PATTER et coll 1954 COLCOCK & VANSANT 1960 STAHLGREN & FERGUSON 1961 BARBER et coll 1962 ATWELL et coll 1965 SCHOFIELD 1965 LENNARD-JONES & STALDER 1967 BRILL et coll 1969 WALLENSTEN 1971 WENCKERT 1971 NUGENT et coll 1973 MARSHAK 1975) On the other hand in the radiologic literature reports discussing particularly recurrent disease are scanty (CHÉRIGIÉ et coll 1973 HILDELL et coll 1980 Part III) recurrence has usually been considered parenthetically in conjunction with descriptions of the original disease

The radiographic features of non operated patients with Crohn s disease were considered previously and the postoperative radiographic appearance of the colon was analysed and discussed (Parts I II III HILDELL et coll 1979 1980) The present communication reports the postoperative radiographic appearance of the new distal ileum and correlates the findings with the preoperative distribution of the lesion the operative procedures employed and the postoperative appearance of the colon

Material and Methods

The material was derived from films and records of 195 consecutive patients operated upon during a 15-year period (1959–1973) Detailed information on the series is given in previous reports (Parts I II III)

The preoperative distribution of the lesions was assessed by a review of preoperative films operative reports and pathologic reports (Part II)

For the present review use was made of the post operative films of all patients in whom the disease preoperatively was located in the distal ileum the colon or in both and who after resectional procedures had an ileo ileal or ileocolic anastomosis or an ileostomy Thus the material consisted of 370 small and 233 large intestine postoperative examinations performed in 150 patients in 1959 to 1976

Most patients were radiographically examined within two years after operation but in the beginning of the series the controls were not as regular and frequent Thus a few patients were not examined until 7 or 8 years postoperatively (More detailed information concerning the radiologic follow up is given in Table 2) The postoperative appearance of the new distal ileum and the colon was recorded and correlated with the preoperative distribution of the lesion and the operative procedures employed (Fig 1)

The period between 1959 and 1973 was divided into two parts one early period 1959 to 1968 during which 70 patients were operated upon and one late period 1969 to 1973 with 80 patients

This subdivision is somewhat arbitrary it is based on the fact that attempts at earlier surgical intervention were made during the last 4 to 6 years and at operation it was aimed at resecting macroscopically involved intestine and also diseased lymph nodes

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	Extent at time of op Op methods	Radiographic appearance of the new distal ileum and the colon after operation for Crohn s disease			
			Abnormalities characteristic of recurrence		
		No radio graphic recurrence	Distal ileum	Distal ileum and colon	Colon
A	5		5		
B	83	54	26	3	
C	11	6	5		
D	2			2	
E	10	1		8	1
F	33	24	9		
G	6	2	4		
	150	87	49	13	1

Fig 1 Correlation between extent of disease at time of operation operative procedures employed and radiographic appearance of the new distal ileum and the remaining colon

Consequently the resections were more extensive during this period

A control material was used for the evaluation of the appearance of the new distal ileum oral to an ileocolic anastomosis This material consisted of films of 100 patients operated upon with resection of the distal ileum and right hemicolonectomy for other diseases than Crohn s disease mainly malignant lesions None of these patients had any evidence of inflammatory disease of the intestine neither pre nor postoperatively A review was made of two small or large intestine examinations in each patient performed with an interval of at least six months The length of the resected ileal segment in these patients varied between 5 and 40 cm (mean 10 cm)

Results

Control material Irregularities in the region of the anastomosis were found in some patients they were considered to be sequential to the operation Otherwise the mucosal folds were regular without radiographic evidence of edema or ulceration (Fig 2)

Crohn s disease The new distal ileum was considered to be normal when the radiographic appearance was the same as in the control material

Lesions observed at radiography consisted of abnormalities due to edema ulceration and fibrosis The lesions were always located in direct contact with an ileocecal valve an ileocolic anastomosis or an ileostomy

Four groups could be distinguished at the end of the observation period

(1) Normal appearance and no clinical evidence of recurrent disease (78 patients Fig 3)

(2) Edema but no ulcers and no progression of the lesions No clinical evidence of recurrence This group is called edema (10 patients, Fig 4)

(3) Radiographic recurrence Abnormalities such as edema ulceration fibrosis and local progression No clinical evidence of recurrence (20 patients) This group is called radiographic recurrence (Fig 5)

(4) Radiographic and clinical evidence of recurrent disease (42 patients) This group is called recurrence (Fig 6)

Groups 3 and 4 are referred to as postoperative ileitis

The patients were distributed within these 4 groups in relation to the preoperative distribution of the lesions as shown in Table 1

Normal appearance of the new distal ileum was recorded in 78 of 150 patients (52%) The frequency of normal appearance was the same in the early as in the late period

Edema was recorded in 10 of 150 patients (7%) and was only observed oral to an ileocolic anastomosis

Radiographic recurrence was noted in 20 of 150 patients (13%) and was observed only oral to the ileocolic anastomosis Three of 70 patients (4%) had radiographic recurrence during the early period and 17 patients of 80 (21%) during the late period The difference is significant (p<0 01)

Recurrence was recorded in 42 of 150 patients (28%) In 22 patients the ileal recurrence was located oral to an ileocolic anastomosis in 13 patients oral to an ileostomy and in 7 patients oral to the ileocecal valve Twenty eight of 70 patients (40%) had recurrence during the early period and 14 of 80 patients (18%) during the late one This difference is significant (p<0 01)



Fig 2



Fig 3



Fig 4

Fig 2 New distal ileum in a patient operated upon with resection of the distal ileum and right hemicolon because of a carcinoid in the distal ileum No edema or ulceration

Fig 3 Normal appearance of the new distal ileum in a patient operated upon for Crohn s disease with resection of the distal ileum and right hemicolon The contour of the intestine is regular the mucosal folds are thin and straight without ulcers

Fig 4 Edema in the new distal ileum oral to an ileocolic anastomosis The mucosal folds are broad but without ulcers



Fig 5 Radiographi recurrence oral to an ileocolic anastomosis The examination wa performed 13 years after the primary opera tion Fibrosis and a inus tract The surviving mucosal island protrudes like a polyp into the lumen of the intestine



Fig 6 Recurrence in the new distal ileum oral to an ileoc anastomosis Marked edema with broad irregular mucosal f and several ulcers in the most aboral part

Repeat radiographs of the small intestine Various aspects are summarized in Table 2 In 63 of the 78 patients with normal appearance of the new distal ileum repeated postoperative examinations were performed all remained normal at the following examinations

Edema which was evident at the first postoperative examination was stationary while radiographic recurrence progressed locally

Recurrence was evident at the first postoperative examination in 39 of 42 patients and in 3 patients whose first examination could not be evaluated at the second

In the majority of patients the first repeat radiography was performed within 3 years after the primary operation in most of them before one year Five patients were examined 3 to 5 years and 3 patients 5 to 8 years after the operation

In 7 patients of the 42 with recurrence the radiographic lesions were demonstrable 3 to 9 years before they had given any clinical evidence of recurr disease Consequently these patients during part the observation period were cases belonging to group radiographic recurrence The difference b tween patients who passed from normal to rec rence (0 of 78 i e 0%) and patients who pass from radiographic recurrence to recurrence (7 of i e 26%) is significant ($p<0.001$)

Comparison between lesions in the new dis ileum and postoperative appearance of the col Postoperative lesions in the colon were of 3 typ (Part III) submucosal edema superficial fluctua colitis and clinical and radiographic recurren The two latter types are referred to as postopera colitis The postoperative appearance of the colon patients with lesions in the new distal ileum appe in Table 3

Postoperative colitis was recorded only in pat with recurrence in the distal ileum (13 of 29 patien Table 3) while in patients with radiographi re

Table 1

Relationship between the postoperative appearance of the new distal ileum and the preoperative distribution of the lesions Figures in parentheses indicate the number of patients operated upon during the early and later period i e 1959–1968/1969–1973

Preoperative localization of lesions	Postoperative appearance of new distal ileum				Total No of patients
	Normal	Edema	Radiographic recurrence	Recurrence	
Distal ileum/cecum	44	10	16	18	88
Distal ileum + right hemicolon	6		4	3	13
Distal ileum + colon	26			17	43
Colon	2			4	6
Total	78 (36/42)	10 (3/7)	20 (3/17)	42 (28/14)	150 (70/80)

Eight patients operated upon with resection of the distal ileum and the right hemicolon

Table 2

Radiologic follow up by small intestine examination

Postoperative appearance of new distal ileum	No of patients	No of examinations	First postoperative examination (mean No of years)	No of patients with multiple examinations	Radiologic follow up (mean No of years)
Normal	78	168	1 3 (0 5–8)	63	6 7 (3–15)
Edema	10	36	1 1 (0 5–7)	8	6 6 (3–15)
Radiographic recurrence	20	82	1 2 (0 5–3)	18	5 4 (3–16)
Recurrence	42	84	1 8 (0 5–7)	34	2 9 (0 5–10)
Total	150	370			

rence or edema the postoperative colon was normal or had submucosal edema

The operative procedures employed and the extent of disease at the time of operation must be considered in order to evaluate the figures in Table 3

In 11 of 150 patients the entire or a great part of the colon was left behind at operation (Fig 1 A–E) Seven of these patients were operated upon with segmental resection of the ileum (A + D) and the remaining 104 with resection of the distal ileum and the right hemicolon (B + C + E)

Considering the presence or absence of postoperative ileitis and postoperative colitis in these 111 patients 4 groups could be distinguished

(1) No evidence of postoperative ileitis or colitis (61 patients B + C + E) The distal ileum and right hemicolon had been resected

(2) Postoperative colitis but no evidence of postoperative ileitis (1 patient E) The distal ileum and right hemicolon resected

(3) Postoperative ileitis but no evidence of postoperative colitis (36 patients A–C) Segmental resection of the ileum (A) was performed in 5 patients (A) resection of the distal ileum and right hemicolon in 31 (B + C)

(4) Postoperative ileitis and postoperative colitis (13 patients B + D + E) Segmental resection of the ileum was performed in 2 patients (D) resection of the distal ileum and right hemicolon in 11 (B + E)

Thus all 7 patients operated upon with segmental resection of the ileum (A + D) had postoperative ileitis and 2 of them (D) also postoperative colitis Both ileal and colonic lesions existed preoperatively The patients were operated upon because of symptoms of small intestine obstruction and at op-

15 80 839

Table 3

Postoperative appearance of the colon related to postoperative lesions in the new distal ileum

New distal ileum	No of patients	Postoperative appearance of the colon			
		Normal	Submucosal edema	Postoperative colitis	
				Superficial colitis	Recurrence
Edema	10	7	3		
Postoperative ileitis					
Radiographic recurrence	20	17	3		
Recurrence	29	12	4	6	7
Total	59	36	10	6	7

eration only a stenotic segment of the aboral ileum was resected

Of 104 patients operated upon with resection of the distal ileum and the right hemicolon 42 had post operative ileitis (B + C + E) and 11 of them also postoperative colitis (B + E) None of these 42 pa tients had any evidence of disease in the ileal seg ments left behind at operation while it was substan tially proved (Part III) that the colonic lesions existed preoperatively in 10 of 11 patients Moreover only one patient had postoperative colitis without postoperative ileitis (in group 2)

Thus in 12 patients a normal ileal segment was operatively connected with a colonic segment af fected by colitis In 11 of these patients (92%) evi dently a linear extension of the lesions had de veloped over the anastomosis to the new distal ileum

On the contrary 31 patients had a postoperative ileitis in segments that were anastomosed to a preoperatively normal colonic segment None of these 31 patients had any evidence of postoperative colitis Thus linear extension across an ileocolic anastomosis was significantly ($p<0.001$) more fre quent in oral than in aboral direction

Postoperative appearance of the new distal ileum oral to an ileostomy Colectomy proctocolectomy and ileostomy were performed in 39 of 150 patients In 26 of these (67%) the new distal ileum had a normal radiographic appearance postoperatively while 13 patients (33%) had a recurrence

In 10 of the 39 patients the length of the resected segment was shorter than 20 cm Nine of these pa tients (90%) had recurrence which should be com pared with 4 recurrences in 29 patients (14%) with resections longer than 20 cm The difference is sig nificant ($p<0.001$)

Discussion

No generally accepted definition of recurrence of Crohn s disease has appeared Most authors have used definitions similar to the one suggested by LENNARD-JONES & STALDER Symptomatic relapse with evidence of recurrent disease at radiographic clinical examination or both If this definition is accepted symptomatic relapse is required for the diagnosis, which cannot be made on radiographic findings only However several authors have com mented parenthetically on the existence of radio graphic lesions compatible with recurrent disease in the new distal ileum of patients without symptoms of recurrence (ATWELL et coll BRILL et coll KRAUSE et coll 1971)

Asymptomatic lesions in the new distal ileum Lesions in the new distal ileum occurred in 30 asymptomatic patients edema in 10 and radio graphic recurrence in 20

These lesions were probably not caused by the operative procedure per se as no abnormalities of these types were observed in the control group However the resection was more extensive in pa tients with Crohn s disease than in the control ma terial The existence and appearance of these lesions may be explained in various ways

They could be secondary to the resection of long segments of the distal ileum If this is true the radiographic abnormalities should be regarded as representative of a chronic lymphedema caused by the operative procedure and particularly by the ex tensive dissection of the lymph nodes The predomi nance of these lesions in the late period may speak in favour of this theory During this period the surgical approach became more intensive and larger seg ments were resected than in the early period

Another explanation could be that the disease was more widespread than could be diagnosed on operation and minor lesions were left behind If this is true the question arises why the patients did not have any symptoms One possible explanation is that patients with edema and radiographic recurrence represent cases of healed disease The disease might have been brought under immunologic control after the surgical removal of the most severely involved segments

However most probably radiographic recurrence may be explained on the basis of individual variations in time between the appearance of radiographic lesions and symptoms Considering the original disease this is well known This explanation is further supported by the fact that 7 patients who initially were cases of radiographic recurrence during the observation period developed symptoms and consequently were transferred to the recurrence group Moreover a significant difference in frequency was found between the early and the late period considering both patients with radiographic recurrence and patients with recurrence It is therefore most probable that some if not all of the patients who at the end of the observation period were considered to have radiographic recurrence in course of time will also develop symptoms The numerical difference between radiographic recurrence and recurrence in the early and late period will then be equalized This is in agreement with the observations of BRILL et coll who found that all patients with radiographic evidence of recurrent disease finally also had clinical evidence

In summary it is most likely that radiographic lesions referred to as radiographic recurrence are manifestations of Crohn s disease Edema should probably be looked upon as sequential to more extensive resections

Radiographic and clinical recurrent disease Most authors agree that in the majority of patients recurrence of the disease is clinically evident within 3 years postoperatively (BRILL et coll FAHRLANDER & BAERLOCHER 1971 GREENSTEIN et coll 1975) However DE DOMBAL et coll (1971) have suggested that there are two types of recurrent disease—one early and one late This opinion is shared by other authors (MARSHAK) and is true also in the present series concerning clinical recurrence of the disease However the results indicate that morphologic abnormalities characteristic of recurrent disease are present shortly after operation although some patients remain asymptomatic for several years Radiographic lesions could be demonstrated at the first postoperative examination of the small intestine in all patients with recurrence during the observation period Moreover no patient with an initially normal postoperative small intestine examination had subsequent recurrence of the disease and these patients were followed for 3 to 16 years (mean 6 7 years) Thus from a radiologic point of view no late recurrences occurred in the present series The vast majority of recurrences was early and all recurrences could be demonstrated at the first postoperative radiographic examination These observations suggest that in the small intestine also recurrent disease is representative of persistent disease The late recurrences described by DE DOMBAL et coll are probably representatives of the same variations of development of postoperative lesions as are radiographic recurrences in the present series

An early diagnosis of recurrent disease can evidently be made on radiographic findings only and will then include recurrence as well as radiographic recurrence i e both late and early recurrences Consequently there should be no need for follow up periods of 10 years or longer to evaluate the results of the surgical management However during the first postoperative years it may be difficult to differentiate between edema and radiographic recurrence and to make a diagnosis of slight inflammatory lesions This means that a period of about 3 years is probably required to obtain an adequate diagnostic accuracy

Localization of the lesions It is obvious that linear extension of the disease over an ileocolic anastomosis occurred only in oral direction (11 of 12 patients) but not in aboral direction In 31 patients with postoperative ileitis the lesions were confined to the ileal side of the anastomosis Reports on postoperative spread of disease from the ileum to the colon can probably be explained by colonic lesions being overlooked preoperatively and left behind on operation At microscopic examination of resected specimens of those of the 31 patients who were operated upon for recurrent disease a sharp borderline was found between the diseased and the non diseased colon This has also been noted by other authors and has not yet been explained One possible explanation might be obtained from the theory of lymphatic spread and non spread that was postulated in previous reports (Parts II III)

It is also obvious that patients in whom less than

20 cm of the distal ileum were resected in conjunction with colectomy ran a significantly higher risk of developing recurrence than patients in whom the resected ileal segment was longer than 20 cm In a previous report the possible inter relationship between the lymphatic drainage of the colon and the small intestine and the distribution of the disease was discussed It was pointed out that especially in the ileocecal region an abundance of anatomic variants appears but that the most aboral 15 to 20 cm of the ileum often have a lymphatic drainage in common with the cecum and part of the ascending colon Thus it is possible that recurrence in these patients was due to exacerbation of lesions left behind on operation or to retrograde spread of the disease from diseased lymph nodes After operation for recurrence only one patient had a second recurrence

In 7 patients resection of a short stenotic segment of the ileum was performed and all developed recurrence At operation most probably the stenosis in itself and changes secondary to it made a proper evaluation of the surrounding parts difficult Microscopic examination of the resected specimens revealed that the resections were not radical and postoperative radiologic examination within two months postoperatively showed profound inflammatory lesions If isolated ileal strictures are located in the aboral segment of the ileum they should be regarded as part of a disease of the distal ileum until otherwise is proved

Prognostic considerations Different statistical methods have been applied to the assessment of the surgical management Expected recurrence rates of about 90 per cent have been reported using the actuarial method (GREENSTEIN et coll)

However the validity of conclusions derived from any method is strongly dependent on the data basis In most reports recurrence is dealt with as an entity and the preoperative extent of disease and the surgical radicalness have not been considered

It is obvious from the results in the present and previous reports (Parts I II III) that proper calculations cannot be made without an intimate knowledge of the preoperative distribution of the lesions When resections were performed on the basis of an erroneous diagnosis of the macroscopic extent of disease the result almost invariably was recurrence of the disease In the colon it was proved that recurrence was due to exacerbation of the disease in segments left behind on operation Most probably this is true also for recurrence in the new distal ileum although for reasons discussed (Parts I II) it cannot be demonstrated with the same evidence as in the colon

It is obvious that in 27 of the 42 patients in the present series who had recurrence the operation was not adequate 5 patients with disease of the distal ileum and 2 patients with ileocolic disease were operated upon with segmental resection of the ileum, in 11 patients with disease of the ileum and the entire colon the distal ileum and the right hemicolon were resected and 9 patients with ileocolic or colic diseases were operated upon with colectomy and a resection of the distal ileum that was shorter than 20 cm

The results in the present and a previous report (Part III) indicate that the risk for these 27 patients to develop recurrence would have been far less if a more adequate type of operation had been carried out

It should also be mentioned that in several of the remaining 15 of 42 patients with recurrence microscopic examination revealed inflammatory lesions in the surface of resection (this will be accounted for in detail in a separate report)

Statistical methods have not yet been applied to the results of the present series for calculation of recurrence rates this will be done when the clinical review of the patients is completed However without using statistics the results indicate that of the 150 patients (Fig 1) 87 with no radiographic evidence of recurrent disease run a low risk of developing recurrence Moreover several of the patients who were reoperated upon for recurrence have had no radiographic evidence of a second recurrence

The results in this series of reports should not be understood as a recommendation for uncritical use of resectional procedures However as long as medical treatment is as disappointing as it is today and most patients sooner or later appear for surgical management continued evaluation of surgical methods is essential It is obvious that some patients preferably should be conservatively managed and surgical intervention be reserved for complications of the disease

In most patients however resectional procedures may be used with good results provided a careful preoperative and operative evaluation of the disease has been performed

SUMMARY

Postoperative films of 150 patients operated upon for Crohn s disease were reviewed with regard to postopera-

.e abnormalities in the new distal ileum The lesions ere always located in the most aboral part of the ileum patients with persistent colonic disease the ileal lesions ere apparently the result of a spread of colonic lesions many of the remaining patients there was strong evi ence that recurrent disease was representative of persist it disease

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ARTHROGRAPHIC DIAGNOSIS OF RUPTURED CALCANEOFIBULAR LIGAMENT

II Clinical evaluation of a new method

M VUUST and B NIEDERMANN

Supination trauma of the ankle joint may cause arious lesions A slight trauma may cause injury to he soft tissue alone In cases of more severe distor ions rupture of the capsule of the antero lateral ispect of the tibiotalar joint may occur as well as upture of the lateral ligaments The anterior alofibular ligament ruptures first If the supination movement continues also the calcaneofibular liga ment ruptures Isolated rupture of the latter ligament is extremely rare (PRINS 1979) Finally in severe cases rupture of the posterior talofibular ligament occurs in addition

Surgical treatment of the more severe cases of ankle joint distortions has been increasingly used in the past which makes an accurate diagnostic method necessary It seems difficult to compare the results in previous reports partly because of different diag nostic methods and partly because of the inaccuracy of these methods PRINS regarded the combined rup ture of the anterior talofibular and the calcaneofibu lar ligament as a major lesion whereas the isolated rupture of the anterior talofibular ligament was re garded as a minor lesion with no need for surgery Therefore the exact diagnosis of these two ligament ruptures is important

In the previous report by VUUST (Part I) the use of an oblique axial projection in arthrography of the ankle has been introduced Criteria were proposed for distinction between ruptures of the anterior talofibular ligament and rupture of both lateral liga ments and these criteria were confirmed on experi mental post mortem lesions The present report evaluates these criteria in a clinical series compar ing their validity to those of other arthrographic criteria

Material and Method

During a four month period 19 patients (12 men 7 women aged between 16 and 54 years average 31) with ankle distortions were operated upon for rup- tured lateral ligaments of the talocrural joint All patients with sprained ankles admitted to the hospi tal in this period were clinically evaluated If rupture of the lateral ligaments was suggested an arthro- graphy was performed within 24 hours after the trau ma If the arthrography revealed a leakage of con trast medium on the antero-lateral aspect of the talocrural joint an oblique axial film was included

Surgery was performed in cases of suggested rup- ture of both lateral ligaments A uniform evaluation of the lesions was secured as only cases operated upon by the same surgeons are included in the ma terial This selection is random and thus the mate rial may be regarded as consecutive

Arthrography was performed by injection of 6 ml meglumine iothalamate (Conray meglumin 282) and 2 ml of 2 per cent Leostesin antero-medially in the talocrural joint followed by passive movements of the ankle

The projections used were antero-posterior later

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Fig 1 Partial rupture of the calcaneofibular ligament Percy type II with contrast medium mainly situated anterior to the lateral malleolus On the a p film (a) the contrast filled peroneal sheath (→) is visible Contrast medium in the malleolar fossa and around the tip of the fibula (↔) on the oblique axial film (c) indicating rupture of the calcaneofibular ligament

al and antero posterior with the foot rotated 20° laterally and medially Furthermore an oblique axial exposure was used as described in Part I It should be emphasized that an exact projection is necessary for the accurate diagnosis In order to demonstrate the reproducibility of this projection in the daily routine the radiologic author did not perform any of the arthrographies included in the present series

Diagnostic criteria Two different types of criteria were used to indicate a rupture of the calcaneofibular ligament Either a type III arthrographic finding according to PERCY et coll (1969) or a contrast leakage on the oblique axial film using the criteria defined in Part I

Filling of the peroneal sheath was not used in this series as an indicator of rupture of the calcaneofibular ligament preoperatively However in a retrospective evaluation, it was compared with the other criteria mentioned (Table)

Table

Relationship between arthrographic criteria and findings at operation

	Isolated rupture of the anterior talofibular ligament	Rupture of both lateral ligaments
Criteria of Percy	9	10
Contrast filling of the peroneal sheath	5	14
Oblique axial film	0	19
Ruptures found at operation	0	19

Operation At the operation a J shaped incision was made anterior to and beneath the lateral malleolus The peroneal sheath was opened in order to obtain a precise estimation of the extension of the lateral ligament lesion The posterior talofibular ligament was not inspected

Results

A rupture of the calcaneofibular ligament was diagnosed correctly in all 19 cases

At operation rupture of both the anterior talofibular ligament and the calcaneofibular ligament was found in all 19 patients In 13 patients both ligaments were totally ruptured while in 6 patients the rupture of the calcaneofibular ligament was partial and combined with a total rupture of the anterior talofibular ligament The antero posterior and lateral films were evaluated using the criteria of PERCY et coll without knowledge of the results from the oblique axial film The diagnostic results using the oblique axial exposures are significantly better than the two other criteria (χ^2 test $p<0.01$ Table)

All cases without filling of the peroneal sheath had a rupture of the sheath at operation

Discussion

The oblique axial projection is more difficult to perform than the standard projections Nevertheless in the present series it was possible to use this



Fig 2 Partial rupture of the calcaneofibular ligament Percy type III with contrast medium mainly situated lateral to the malleolus no filling of the peroneal sheath Two tongues of contrast medium the medial one indicating ruptured calcaneofibular ligament on the oblique axial film (c) Position of the ligament between arrows



Fig 3 Total rupture of the calcaneofibular ligament No filling of the peroneal sheath Ruptured calcaneofibular ligament on the oblique axial film (c) Nearly identical appearance of contrast medium as in Fig 2c

projection in the daily routine without special experience and with a high diagnostic accuracy

No patients were operated upon if only an isolated rupture of the talofibular ligament was suggested No direct conclusions can therefore be drawn as to the possibility of a false normal calcaneofibular ligament (i e a ruptured ligament not indicated at arthrography) However since the diagnostic accuracy of the criteria of PERCY et coll in the present series equals that of the series of LINDHOLMER et coll (1978) where all cases with possible lateral ligament ruptures were operated upon it can indirectly be concluded that an erroneously normal ligament based on the oblique axial film does not play a major role

However after this series had been concluded one erroneous diagnosis occurred In a patient with a total rupture of the anterior talofibular and the

calcaneofibular ligament the arthrographic finding was that of a Percy type III On the oblique axial exposure a leakage was observed lateral to the malleolus but the contrast medium in the malleolar fossa had a well defined straight border at the position of the calcaneofibular ligament which consequently was assumed to be intact The reason for this finding is not known but it might be caused by too few passive movements after the injection of the contrast medium

The appearance of the leakage described in Part I (VUUST) corresponded to what occurred in the clinical series (Figs 1 2 3) It is possible to distinguish the contrast medium that extends around the lateral aspect of the malleolus from that situated beneath and medial to the tip of the fibula in the malleolar fossa Only the latter indicates a rupture of the calcaneofibular ligament

Filling of the peroneal sheath was a better criterion on rupture of the lateral ligaments than the extension of the contrast medium on the antero posterior and lateral films the correct diagnosis was 74 per cent This figure is not absolute since peroneal filling was not used preoperatively as an indicator of the calcaneofibular ligament rupture The result is in agreement with that of SPIEGEL et coll (1975) STAPLES (1975) LINDHOLMER et coll and PRINS However BROSTRÖM et coll (1965) found that such a filling was a reliable criterion for the calcaneofibular ligament rupture In the present series no filling of the peroneal sheath occurred in 5 cases desp
rupture of the sheath found at operation

SUMMARY

The validity of a new criterion for the arthrograph
diagnosis of rupture of the calcaneofibular ligament i
compared to that of other arthrographic criteria in a clini
cal series The new criterion is found to be more reliab
than those previously used

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ROM THE DEPARTMENT OF ORTHOPAEDIC SURGERY RIGSHOSPITALET DK 2100 COPENHAGEN AND THE CYCLOTRON DEPARTMENT THE NIELS BOHR INSTITUTE DK 2100 COPENHAGEN DENMARK

NUMERICAL ASSESSMENT OF ASYMMETRY AT SCINTIGRAPHY OF NORMAL JOINT PAIRS WITH $^{99}Tc^{m}$ POLYPHOSPHATE

M NØRBJERG J HEERFORDT I DISSING M JENSEN
J MØLLER and O SNEPPEN

The normal $^{99}Tc^{m}$ polyphosphate scintigram is usually described as being symmetric (CHARKES et coll 1973 CITRIN 1977) Only in a few reports has attention been paid to non pathologic asymmetry in articular accumulation of tracer THRALL et coll (1974) noted asymmetry in the shoulder region in 19 of 150 patients in 17 of these 19 cases the uptake was higher in the right shoulder Similar but less marked differences have been found in the hips and knees GENOE & MOELLER (1974) observed a few cases of asymmetric accumulation in otherwise normal shoulders and MERRICK (1975) found that the shoulder of the dominant side often has a higher uptake SEBES et coll (1976) found right sided preponderance in the shoulders of 30 of 100 right sided patients and left sided preponderance in only 5 of the same group

All these reports have been based solely upon visual evaluation of the scintigrams As numerical assessment enables a more exact graduation such an analysis of the symmetry in some non pathologic joints was considered to be of interest It was performed in retrospect

Method

Scintigraphy using a 5 inch (12 5 cm) dual probe whole body rectilinear scanner with video-display processor (Elscint) was carried out 2 to 2½ hours after the administration of 444 MBq (12 mCi) $^{99}Tc^{m}$ polyphosphate Particular care was taken in correct positioning of the patients in order to avoid position dependent asymmetries The images were stored on magnetic tape for later numerical analysis on the video-display unit Each joint was framed and the total number of counts within the frame was read on a numerical display For each pair of joints a ratio was calculated if the number of counts was higher in the right joint the ratio was defined as pointing to the right and vice versa

Statistically the number of counts within each frame was assumed to follow a Poisson distribution The standard deviation (SD) of the ratio (R) is

$$SD=R\times\sqrt{\frac{1}{x}+\frac{1}{y}}$$

where x is the number of counts in the frame of one side and y the number of counts in the other frame The ratio is said to point significantly to the right or left if $R-SD>1$

Material

The material comprised all recorded cases of $^{99}Tc^{m}$ polyphosphate bone scintigraphy in patients from this orthopaedic department during the period 1973 through 1977 excluding (1) images not technically suitable for numerical analysis (2) images with asymmetric positioning of the patients and (3) images from patients with systemic diseases such as rheumatoid arthritis osteoporosis etc

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Table

Right left variation in joint regions

Joint pair	Ratio pointing significantly to right		Ratio pointing significantly to left		Ratio not significantly deviating from 1		Total	
	No	Per cent	No	Per cent	No	Per cent	No	Per cent
Shoulder	13?	51	46	18	82	31	?60	100
Sacroiliac	132	32	77	19	205	49	414	100
Knee	99	40	67	27	83	33	249	100
Ankle	65	30	51	24	98	46	214	100
Tarsus	67	32	43	20	101	48	211	100
Total	495	37	?84	21	569	42	1 348	100

A total of 534 images remained for analysis some of these included only a few or a single pair of joints

It is well known that a focal osseous lesion may entail increased tracer accumulation not only locally but also diffusely in the affected bone and possibly also in the adjacent joints (THRALL et coll 1974 1975 BESSLER 1975 GOLDMAN & BRAUNSTEIN 1976 PFANNENSTIEL & SEMMLER 1977) Therefore from these 534 bone images the joint regions in the vicinity of a focal bone lesion were excluded Thus a focal lesion of one tibia excluded the knee and ankle regions etc Hip joints were excluded as by the method used it was impossible to avoid superimposition of the pelvis Elbow and wrists were also excluded as the relatively low count rate in these regions induced larger errors in the calculation of the ratio

After this further selection the 534 images include 1 348 joint pairs suitable for evaluation of non pathologic asymmetry (Table)

Results

In the material as a whole a significant right sided dominance was evident in 37 per cent a significant left sided dominance in 21 per cent and an apparently symmetric accumulation in 42 per cent (Table) In shoulder and knee images asymmetric distribution was relatively frequent (about 70%) as compared with that in the sacroiliac ankle and tarsal joints (about 50%)

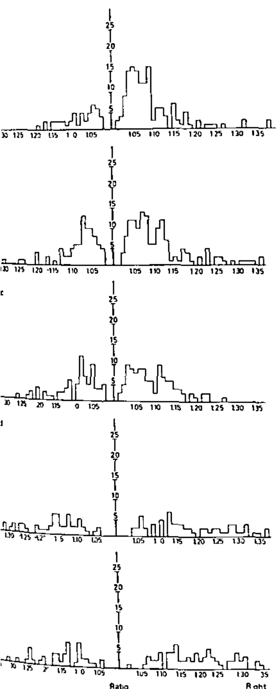
The frequency of a significantly right pointing ratio was highest in the shoulder joints (51%) somewhat lower in the knees (40%) and still lower in the remaining joints The distribution of the cases by the size of the ratio is presented in the Figure which demonstrates not only a majority with a right pointing ratio but also among these cases a relatively large number with a marked deviation of the ratio

Discussion

The most common source of asymmetric scintigraphic delineation of corresponding joint regions in normal individuals is no doubt an asymmetric positioning of the patient by exclusion of images from asymmetrically positioned patients the asymmetries in the present series are assumed to reflect actual right left variations in tracer distribution

On the whole the asymmetries were rather small the mean value of significant ratios being around 1 10 to 1 25 and in a large number of cases not convincingly assessable visually This may be the explanation for the higher frequency of asymmetry in the present series as compared with previous reports (THRALL et coll 1974 SEBES et coll) The former authors encountered asymmetry more often in the shoulders than in the knees This agrees with the present results the most common asymmetric distribution occurring in shoulder joints the next most common in knee joints and the least common in the sacroiliac ankle and tarsal joints

Unrecognized wear and tear phenomena have previously been suggested as a predominant cause of increased accumulation of tracer in non pathologic joints (SEBES et coll) In the knee joints in particular this is a conceivable cause of asymmetry Otherwise the reason for the asymmetry



tribution of asymmetry according to the ratio Only ratios nificantly deviating from 1 are included a) Shoulder b) sacro- c) knee d) ankle and e) tarsal joints

d especially for the increased accumulation in the ht sided joints has mainly been attributed to side minance (MERRICK JAJIĆ et coll 1978 SEBES et ll) A generally less marked increase in right ded accumulation in the joints of the lower limbs HRALL et coll 1974) might then be ascribed to the ress being more uniform in the lower than in the per limbs

The lower frequency of asymmetry in the ankle and tarsal joints in the present series may be as cribed to the relatively greater measurement error in these ratios due to fewer counts in these regions The similarly lower frequency of asymmetry in the sacroiliac joints must be viewed in the light of superimposition of a considerable soft tissue layer on the osseous tissue tending to mask a possible side difference in osseous distribution

Conclusion In visual assessment of bone scinti graphy images slightly asymmetric distribution can hardly lead to erroneous evaluation but if the ac cumulation is to be evaluated more objectively numerical analysis is necessary (BAUER 1975 SNEP PEN et coll *1978)* For diagnostic application of such numerical assessment normal ranges of physiologic asymmetry must be defined based upon anatomic regions and possible side dependent variations

SUMMARY

Numerical analysis of ^{99}Tc^m polyphosphate distribution in 1348 selected non pathologic joint pairs revealed a significantly higher right sided accumulation in 37 per cent a left sided dominance in 21 per cent and no signifi cant side difference in the remaining 42 per cent The most common level of asymmetry was the shoulder joint

ACKNOWLEDGEMENTS

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FROM THE DEPARTMENT OF RADIOLOGY AND NUCLEAR MEDICINE FREIE UNIVERSITAT BERLIN D-1000 BERLIN AND THE RESEARCH LABORATORIES SCHERING AG D-1000 BERLIN GERMANY

CONTRAST MEDIA FOR COMPUTER TOMOGRAPHY OF THE LIVER

O H WEGENER W MUTZEL and R SOUCHON

Computer tomography has not rendered contrast media redundant Two well proven groups of substances are available for the intravenous injection of ionic contrast media urographic and cholegraphic The rational use of these media in abdominal computer tomography is now reported based on experiences from a clinical series animal and phantom experiments

Material and Method

An EMI CT 5005/12 general purpose scanner with scanning time of 20 seconds was used With an image matrix of 320×320 the SD of a standardized water phantom was 1 6 per cent i e ±8 EU (EMI units) 1 EU=2 Hounsfield units (HU) The animals were scanned at 120 kV and the patients at 140 kV

Phantom experiment A plexiglass phantom (Fig 1) with a diameter of 18 cm with cylindric boreholes of varying diameters was scanned using a field size of 25 cm The image of the boreholes with a scanning field size of 32 0 cm diameter would correspond to an object diameter of 1 28 to 60 mm By variation of the photomultiplier tension the SD of the individual dots of the image was varied from the optimum of 1 5 to 63 EU For one measurement series a potassium iodide solution was introduced at varying concentrations An additional homogeneity correction for plexiglass was performed (wedge correction) in order to reduce shading within the phantom

Clinical series Volunteers without any clinically known liver disease were selected The level of the section was determined before the injection of the contrast medium in order to avoid motion artefacts roughly at the level of the phrenico-costal sinus The contrast medium was injected as a bolus within one minute This layer of the liver was scanned at preselected intervals up to 120 min after the injection During the scan blood samples were taken in order to determine the iodine plasma level The doses were 0 4 0 6 and 0 9 g I/kg body weight as meglumine diatrizoate

Evaluation An area of at least 2 000 volume elements was selected and the mean value (with SD) determined for the entire series The central cylinder representing the aorta was exactly fixed using a special program and the attenuation measured The iodine content of the blood samples was determined according to Sandell Kolthoff by means of the Technicon Autoanalyser

Animal experiments were performed in the dog (beagle) Intubation was carried out under phenobarbital sodium anaesthesia and relaxation obtained with succinylcholine chloride The anaesthesia was continued with nitrous oxide During the 20-second scan breathing was suspended on expiration

Dosage *cholegraphic medium* meglumine iotroxinate (Biliscopin) 70 mg/kg body weight intravenously *urographic media* (1) meglumine diatrizoate (Angiografin) (2) meglumine ioglycinate (Rayvist) (3) SH H 340 AB (non ionic) (4) CT 345 and (5) CT 346 (the last development preparations of Schering AG Berlin Bergkamen) for bolus technique 360 mg I/kg body weight was used and for infusion 50 mg I/min/kg body weight intravenously

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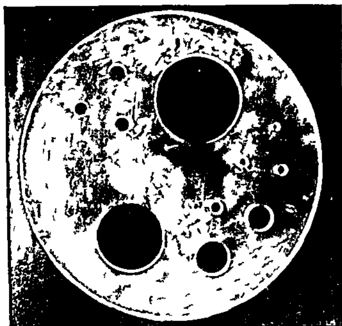


Fig 1



Fig 2a



Fig 2b

Fig 1 Plexiglass phantom with cylindric boreholes of various sizes

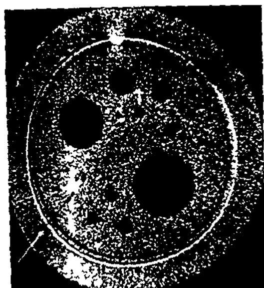
Fig 2 CT section through dog liver a) Before and b) after injection of contrast medium The evaluation field appears in (b)

The same section of the liver as in the clinical series was scanned at preselected intervals and the attenuation measured over the same area for the entire series (at least 1 000 volume elements Fig 2)

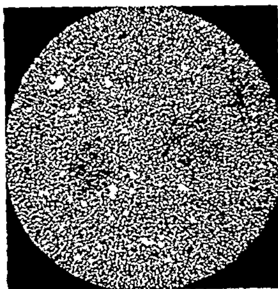
Basic considerations

A high attenuation resolving power of the computer tomography and enhancement of the differences in tissue attenuation by means of contrast media are prerequisites for diagnosing small lesions or those with a similar attenuation to that of the surrounding tissue It is the high attenuation resolving power of computer tomography that gives it an advantage over conventional radiography It is described by

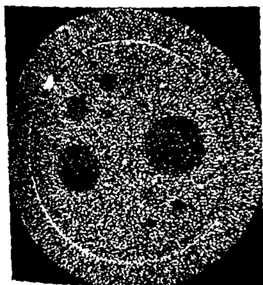
Fig 3 Computer tomography of the plexiglass phantom at various standard deviations (noise) of the image elements a Boreholes filled with water Even the smallest borehole (1.25 mm in diameter) is detectable (→) A detail with a diameter of 10 mm (↔) SD±3 FU b–f) Contrast 19 EU As the SD falls the smaller boreholes also become visible b) SD±63 EU c) SD ... EU d) SD±13 EU e) SD±7 EU f) SD±3 FU



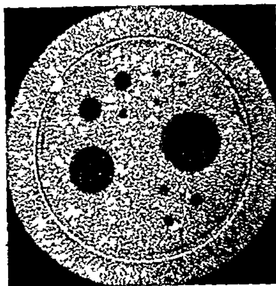
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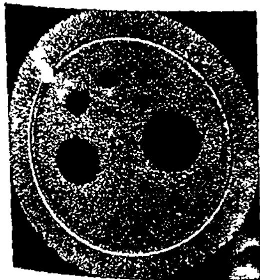
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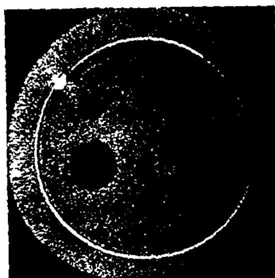
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e



f

Fig 3 (For legend see opposite page.)

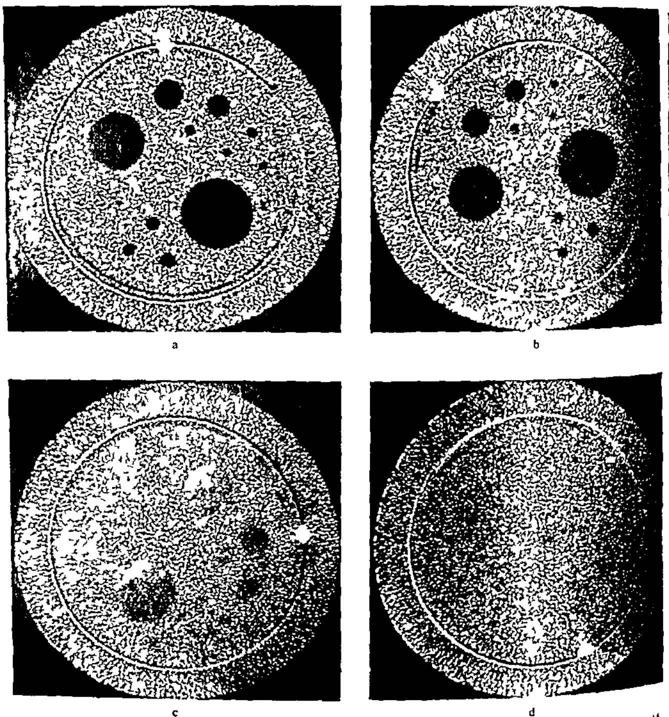
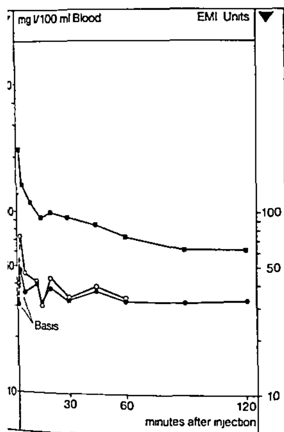
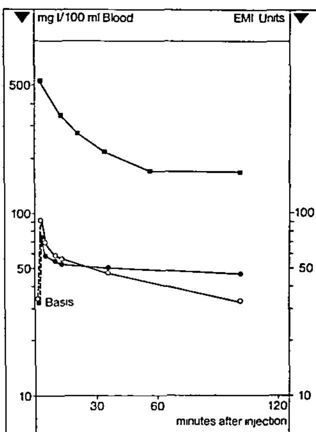


Fig 4 Computer tomography of the plexiglass phantom at different contrasts SD at ±13 EU corresponds to in vivo values over the human liver Not until the contrast is 19 EU (1 5 times SD) are details down to 6 mm in diameter easily visible Contrast in a) [illegible] EU b) 19 EU c) 9 EU d) 1 EU

the SD of the individual dot in the image around a mean value the attenuation value of a homogeneous material These fluctuations appear on the image as noise and are caused by *variation of* the photon flux and the signal processing Fig 3 shows how increasing noise is accompanied *by* an obvious reduction in the visibility of *small zones of lesser* attenuation In order to improve visibility the noise must be reduced or the radiation dose increased Due to the smaller radiation volume and the usually higher radiation dose the SD of the individual dots of the image of a cranial scan is considerably smaller (about 5 times) than in the whole body field (Fig 3c f) However limits to increase the radiation dose obviously exist For this reason the attenuation differences are enhanced using contrast media This raises the ques



a



b

5 Blood level and enhancement of liver and aorta after ...venous injection of a) 0 4 g I/kg b w ($t_{\frac{1}{2}}$ 112 min) and b) 0 9 g ...b w as meglumine diatrizoate ■ Blood O Aorta ● Liver

...n of how much such an enhancement is desirable ...d reasonable

The phantom experiments show that even in the ...esence of considerable noise larger areas are still ...cognizable when small ones have already disap...ared Higher contrast alone can demonstrate ...all zones of lesser attenuation down to a diameter ...less than 1 cm Thus for computer tomography ...in general radiology detail contrast diagrams can ...produced The question of the enhancement de...red is at the same time a question of the size of the ...sion to be detected The competing procedures—...trasound and scintigraphy—set the criterion if ...mputer tomography is to be better than these it ...ould be able to demonstrate lesions with a diame...r less than 1 cm

Under routine conditions (20 s scanning time im...ge matrix 320×320) an SD of 12±2 EU is obtained ...the area of the liver Areas less than 1 0 cm in ...iameter can hardly be detected (Fig 4 c) and those ...f 1 2 to 1 6 cm in diameter are only just detectable ...the attenuation difference to the surrounding area is somewhat less than 1 SD (9 EU) Only a contrast of 1 5 SD (19 EU) can reliably demonstrate the areas of lesser attenuation down to a diameter of 6 mm

This phantom experiment can only serve as a basis for estimation since it is not unconditionally transferrable to the demonstration of the liver in vivo The reasons for this are as follows

A background of optimum homogeneity can be obtained which is impossible in the liver having morphologic structures such as the vena porta system Moreover even small artefacts can influence the detectability in the borderline area

The holes in the phantom are punched out with sharp edges giving optimum contrast The lesions in the liver are not sharply defined and have irregular outline A metastasis can approximately be compared with a small sphere

The cylindric form of the holes furthermore prevents the partial volume effect which may arise in the liver in all lesions smaller than twice the width of the layer

Since the conditions for obtaining an image in vivo

Table

Dose dependent enhancement over the base values of aorta and liver in EU after bolus injection of meglumine diatrizoate

Dose (g I/kg b w)	Aorta 2 min	Aorta 9 min	Aorta 20 min	Liver 2 min	Liver 9 min	Liver 20 min
0 4	49	22	15	16	13	8
0 4	32	3	3	16	11	6
0 6	35	23	19	19	18	15
0 6	51	18	20	26	22	17
0 6	38	20	16	22	13	11
0 9	78	32	31	41	20	20
0 9	57	25	(17)	41	21	16

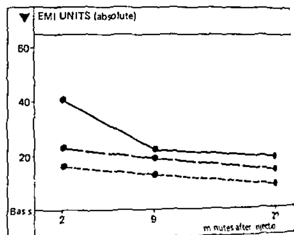


Fig 6 Enhancement of the liver at 2 9 and 20 min after bolus injection of meglumine diatrizoate dependent upon the iodine dose applied 0 4 --- 0 6 and — 0 9 g I/kg b w

are less favourable a contrast of at least 2 SD between pathologic and normal tissue is obviously necessary Thus an enhancement necessary to make a lesion with a diameter of 1 cm visible against the surrounding tissue of similar attenuation must amount to at least twice the SD Admittedly parenchymal lesions of large areas in theory require smaller quantities of contrast medium in order to be detected in practice however superimpositions of artefacts actually call for higher enhancement

Results

Clinical series

A chronologic representation of two typical developments of the attenuation values over the liver and aorta (blood) after bolus injection of 0 4 and 0 9 g I/kg meglumine diatrizoate appears in Fig 5

Immediately after the injection the values over aorta and liver fall more steeply than later on Higher dosages show most clearly the different rates of fall in the enhancement of liver tissue and blood (aorta) The aortic values which are at first higher than those of the liver fall below the latter after about 15 min (Fig 5 b) The uneven course of the attenuation curves in Fig 5 a is due to artefacts and hardly shows the intersection of the two curves

The Table gives the position for three time intervals (2 9 and 20 min) for the three dosages selected (0 4 0 6 and 0 9 g I/kg body weight) the following common features can be deduced

Higher dosages produce higher initial and higher long term enhancement A higher dosage has the strongest effect on both liver and aorta during the

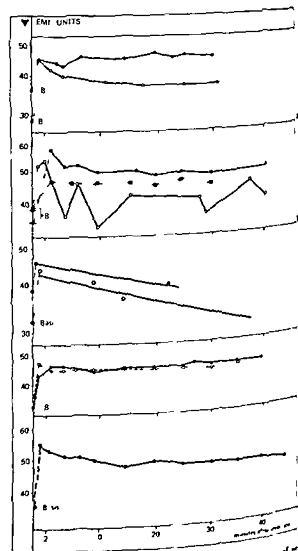


Fig 7 Enhancement of dog liver after bolus injection of angiographic media Each curve represents one experimental series a) ... b) Meglumine ioglycinate c) ... Meglumine diatrizoate b) Meglumine ioglycinate (t½ 65 and 89 min) d) CT ... contrast medium SH H 340 AB (t½ 65 and 89 min) ... CT 346

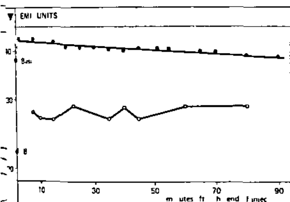


Fig 8 Enhancement of dog liver after intravenous injection of meglumine iotroxinate $t_{\frac{1}{2}}$ about 10 h

first minutes after injection 40 EU at 0 9 g I/kg body weight compared with 16 EU at 0 4 g I/kg body weight After 9 min the enhancements of the different dosages approach each other lying between 11 and ?? EU (Fig 6)

The iodine plasma level has decreased to half the original one at 92 min (±29) and corresponds then to that of the attenuation values over the aorta at 120 min (±?0) The enhancement over the liver lasts 2 to times as long

The results of the phantom experiments may be concluded as follows for practical use

According to dosage the enhancement is below the value of twice the SD of the individual dot in the image i e 25 EU between 2 and 9 min after the bolus injection

Animal experiments

Bolus injection of urographic media The decrease in enhancement for various contrast media appears in Fig 7 The curves allow the following conclusions

At 5 to 15 EU the enhancement with all urographic media is of the same order of magnitude

Due to the differences between the curves caused by artefacts neither the half life of meglumine diatrizoate nor that of meglumine ioglycinate can be determined with certainty but it is at any rate less than ?00 min

The half life of the non ionic contrast medium SH H 340 AB at 65 min and 89 min is definitely shorter than that of the ionic contrast media

The CT 345 and CT 346 contrast media at present under development have a very slow decrease in enhancement Of the two the di iodized form (CT 346) produces a somewhat higher (initial) enhancement

Bolus injection of a cholegraphic medium (meglumine iotroxinate) At the normal human dose of 0 07 g I/kg body weight a maximum enhancement of 8 EU was obtained (Fig 8)

Bolus injection of cholegraphic plus urographic medium The sequential application of meglumine iotroxinate and meglumine diatrizoate (same dosages as before) leads for a short period to a maximum enhancement of 18 EU (Fig 9) The two components work on the whole additively The mixing of meglumine iotroxinate and meglumine ioglycinate resulted in a slightly lower contrast of the liver tissue 10 EU The half life was comparable to that of a cholegraphic medium (Fig 9 b)

Infusion of urographic media Higher enhancement is only attainable with an infusion technique (Fig 10) For both meglumine diatrizoate and CT 345 an enhancement of 45 EU is obtained after 60 min (end of the infusion) A shorter infusion period leads to lower contrast (Fig 10)

Discussion

In the phantom experiments the limitations occurring in conditions in vivo were stated It is a question of relative contrast between lesion and surrounding tissue Only if the pathologic process is enhanced slightly or not at all is the required 25 EU enhancement of the surrounding tissue sufficient In most avascular and hypovascular lesions of the liver (metastases) this condition is probably as a rule fulfilled On the other hand if the pathologic process is enhanced higher enhancement of the surrounding tissue is necessary Finally the administration of a contrast medium may conceal more highly vascularized lesions (hypernephroma metastases STANLEY et coll 1976 1977) This is also the reason why it is not feasible to give overall valid directions for the application of contrast media in abdominal computer tomography

The cholegraphic media are taken up selectively and excreted by the intact liver cell However the limited cellular transport maximum must be considered Thus despite the organ specificity limits to the enhancement of the hepatic parenchyma exist Therefore even in infusion cholegraphy with a large amount of contrast medium a higher enhancement cannot be expected than with a bolus injection However the enhancement obtainable after a bolus

injection (~8 EU) is hardly sufficient considering that in the present experiments the normal generally tolerable dose was administered Only in vascularized lesions of the liver could cholegraphic media perhaps be used supportively as the results in the clinical series suggested

The groups of media were investigated that have hitherto been commonly used and whose properties are widely known The iodized oily emulsions at present under development that have been reported by LAVAL JEANTET et coll (1976) and VERMESS et coll (1976) did attain a greater enhancement (30–50 HU) in an analogous animal experiment (ALFIDI & LAVAL JEANTET 1976) but the hepatocellular reaction may give cause for concern The infusion technique gives higher enhancement (90 HU) but still offers the advantage of greater controllability Although the experiments were carried out in a state of suspended respiration in several of the animals artefacts could not be completely eliminated The curves of Figs 7b and 8 show the effect of these interference factors which did not allow an exact determination of the half lives However the average image quality was quite satisfactory and almost free from artefacts

Conclusions

(1) With urographic media it is possible to obtain higher enhancement of the liver than with cholegraphic media

(2) Bolus injection of urographic media requires a higher dosage of contrast medium and a rapid scanning process

(3) In examination of the liver the infusion of urographic media is clearly superior to the bolus technique

(4) Even in cases of moderate vascularization of small hepatic lesions the lesions can be rendered visible by the infusion of urographic media

SUMMARY

A simple phantom experiment indicates that the enhancement of abdominal organs should be twice the SD of noise in a CT image The enhancement of liver tissue by urographic and biligraphic contrast media is analysed in clinical series and animal experiments Various substances applied alone and in combination were investigated At present only the infusion technique of urographic media provides a sufficient enhancement of liver tissue

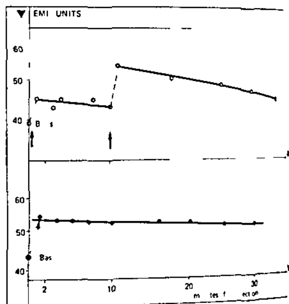


Fig 9 Enhancement of dog liver after intravenous injection of combinations of urographic and cholegraphic media a) First injection of meglumine iotroxinate (Biliscopin 4 4 ml $t_{½}$ about … min) and second injection of meglumine diatrizoate (Angiografin 12 ml $t_{½}$ about 100 min) b) Mixture of meglumine iotroxinate and meglumine ioglycinate ($t_{½}$ about 6 h)

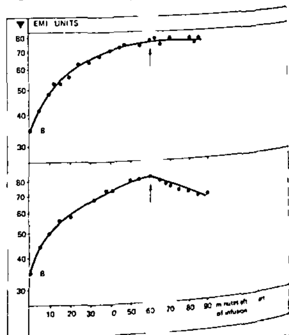


Fig 10 Enhancement of dog liver after intravenous infusion of urographic media a) Diatrizoate sodium b) CT 35 End of infusion indicated by arrows

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PREVENTION OF EXPERIMENTAL VENOUS THROMBOSIS INDUCED BY CONTRAST MEDIUM IN THE RAT

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Deep venous thrombosis is the most feared complication of phlebography Although its real incidence is unknown values as high as 24 to 33 per cent of possible thrombosis after phlebography have been published (BETTMANN & PAULIN 1977 ALBRECHTSSON & OLSSON 1976 1979) Infusion of fluids with or without heparin to wash out the veins after the contrast medium injection has been largely used in order to reduce this complication (KAKKAR 1977 KALAF 1973 ATHANASOULIS 1975 BETTMANN & PAULIN I EA THOMAS & MACDONALD 1978 STAMATAKIS et coll 1978) The clinical experience at this hospital in Botucatu with infusion of physiologic saline containing heparin during and after phlebography seems to confirm the preventive action of heparin The effect of various wash-out procedures on thrombosis induced by contrast medium was assessed experimentally in the rat for an evaluation of the usefulness of this method

Material and Methods

Sixty albino rats of the Wistar strain weighing from 200 to 300 g were used The left jugular vein was carefully dissected free under ether anesthesia and a segment about one cm long was isolated between two vascular clips The blood within this segment was withdrawn through a 3 gauge needle and a small volume of sodium diatrizoate (Hypaque 50% Winthrop) sufficient to fill the segment was injected After 10 min the clips were removed and blood was allowed to recirculate in the vein Details of this method have been described previously (MAFFEI et coll 1977) The animals were then included by randomization in one of the following groups

Group I Control No treatment after induction of thrombosis

Group II Infusion of 2 5 ml of physiologic saline during 5 min through a 3 gauge needle placed cephalad to the site of the first puncture in the left jugular vein

Group III Infusion of 25 U of sodium heparin in 2 5 ml of saline as in group II

Group IV Infusion of 25 U of sodium heparin in 2 5 ml of saline during 5 min in the right jugular vein

The incision was then sutured and the animal allowed to recover After 48 hours the incision was reopened under ether anesthesia the vein inspected and opened to see whether bleeding occurred The whole segment was then resected fixed in formalin 10% and embedded in paraffin The tissues were stained with hematoxylin-eosin elastic van Gieson and toluidine blue and examined microscopically

In another group of 5 rats the effect on coagulation of the given amount of heparin was assessed Under light ether anesthesia the tip of the rat s tail was cut off and 0 5 ml of blood was allowed to drop into a clean glass tube This was immediately placed in a water bath at 37°C and the clotting time was measured Twenty five units of heparin in 2 5 ml of saline were then injected into the vein of the penis and the clotting time measured after 30 60 240 and 270 min

Results of the four treatment groups were statis

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tically analysed by applying the test for contrast among multinomial populations (GOODMAN 1964) and the test on simultaneous confidence intervals for multinomial proportions (GOODMAN 1965) for an α of 0 05

Results

The incidence of thrombosis in the various groups appears in the Table Occlusive thrombus was significantly more frequent in Group I (control group) and in Group II (saline infusion only) than in the groups given heparin No difference was observed in the incidence of mural thrombosis for the different groups Absence of thrombus was significantly more frequent in the two groups given heparin without any difference between these two groups being apparent

When comparing the frequency of the various types of thrombus within the four groups the control and saline treated groups behaved similarly on application of the test for simultaneous confidence intervals for multinomial proportions for both groups occlusive thrombi were significantly more frequent than mural thrombi and absence of thrombi The heparin treated groups behaved differently no significant difference in the frequency of occlusive or mural thrombi or absence of thrombi was found in the systemic heparin group in contrast to the group with local wash out with heparin In this latter group occlusive and mural thrombi were significantly less frequent than absence of thrombus

Most veins without thrombosis appeared normal when inspected in situ on section of the vein profuse bleeding occurred However some veins were contracted and pale and little bleeding occurred when they were sectioned Microscopic examination revealed an acute slight adventitial inflammatory reaction The endothelium was preserved in most of the sections and looked normal except in one case in which it was swollen with degenerative lesions

The veins with thrombosis were distended and had a dark brown colour On section no bleeding occurred and the thrombus had a uniform dark red appearance Microscopically the thrombi were of three types Red formed mainly by red blood cells sometimes with small aggregates of platelets in a framework of fibrin fibrinous when fibrin was the main element of the thrombus and mixed when fibrin red cells and other blood cells were observed

Table

Incidence of thrombosis induced by contrast medium in the jugular vein of rats Effect of different types of treatment Percentage given in parentheses

Result	Treatment			
	Control	Wash out physiologic saline	Wash-out saline+ heparin	Systemic saline heparin
Occlusive thrombus	14 (93)	14 (93)	1 (7)	4 ([illegible])
Mural thrombus	1 (7)	1 (7)	3 (20)	3 ([illegible])
Absence of thrombus	0 (0)	0 (0)	11 (73)	8 ([illegible])
Total	15 (100)	15 (100)	15 (100)	15 (100)

The endothelium was absent in all the thrombosed veins As for veins without thrombosis an inflammatory reaction around the vein was observed

The mean clotting time in the 5 normal rats before administration of heparin was 1 5±0 49 min It was prolonged about 30 times 30 min after intravenous injection of heparin in all animals (mean 47±5 2 min) returning to initial values after 240 min

Discussion

It was possible to induce thrombosis in the jugular vein of rats with sodium diatrizoate as it had been previously with sclerosing substances (MAFFEI et coll 1972) However although contrast medium produces endothelial injury (RITCHIE et coll 19[illegible]) it was not the only cause of the development of a thrombus The endothelial trauma caused by the clips and puncture and the stasis leading to ischemia were also important factors the significance of these factors has previously been demonstrated In a series of 15 rats and 15 guinea pigs thrombosis occurred in 50 to 60 per cent after saline infusion only (unpublished data)

The local wash out of the vein with physiologic saline was not effective in preventing the formation of a thrombus in the present experimental model On the other hand when heparin was added to the infusion fluid the incidence of thrombosis was significantly reduced Systemic heparin also prevented thrombus formation although it seemed less effective

The heparin was given only once and in a relatively low dose similar to the one used at phlebography in man As the clotting time in rats with the used dosage of heparin was normal after 4 hours suggesting low or no action of heparin after this time it appears that the initial period was vital for the development of thrombosis In rats and in guinea pigs subcutaneous injections of low dose heparin did not prevent thrombosis induced by sclerosing substances even when given every 12 hours (MAFFEI et coll 1972 1977) Therefore a high blood level of heparin established immediately after intravenous injection is probably an important factor in preventing the development of a thrombus

The mechanism of heparin in preventing thrombosis in the experimental model is complex The absence of endothelial cells in some of the sections of veins without thrombus would favour the hypothesis that heparin inhibits the initial aggregation of platelets or fibrin deposition on the exposed collagenous tissue However the sustained absence of thrombi 48 hours after heparin injection with endothelial lesion still present is difficult to explain in view of the normal clotting time of the blood at four hours Another possibility is that heparin acts on a not completely injured endothelium inhibiting a transitory release or activation of substances or impeding an alteration of electric potentials as suggested by SAWYER et coll (1973) all factors which would enhance platelet aggregation or fibrin formation This second hypothesis means that the complete destruction of endothelial cells observed in all sections of thrombosed veins must have occurred secondarily to the thrombus formation

Although both groups given heparin were significantly different from the control and saline groups the local wash out with heparin had a better effect than systemic heparin

The concentration of heparin in the endothelium is up to 7500 times higher than in the blood after intravenous heparin injection in rats (HIEBERT & JAQUES 1976) Thus it may be assumed that large amounts of heparin entered the endothelium at the site of the injection due to a higher local blood concentration of heparin which accounted for the better results in the local wash-out group

Although experimental data cannot be transferred directly to human beings the results may explain the low incidence of deep venous thrombosis following phlebography when heparin is used to wash out veins during and after the examination

SUMMARY

In order to assess experimentally the usefulness of some procedures employed in man to prevent venous thrombosis following phlebography thrombosis was induced in rats using sodium diatrizoate in a temporarily isolated segment of a jugular vein The prevention of thrombosis was attempted by washing out the vein with physiologic saline or saline plus heparin or by injecting saline plus heparin in the opposite jugular vein Thrombosis occurred in all animals in the control group and in the group treated with saline alone Both treatment schemes with heparin significantly reduced the incidence of thrombosis the wash out with heparin being more effective than systemic heparin

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MODIFICATION OF GREY SCALE IN COMPUTER TOMOGRAPHIC IMAGES

A HEMMINGSSON and B JUNG

Several authors (KIRKPATRICK et coll 1978 STEPHENS et coll 1977 BRYAN et coll 1977) claim that CT images often should be displayed with a narrow window setting (50–100 old Hounsfield units Hn) Parts of the image outside the selected band then appear completely black or white This might detract from the evaluation of the image and essential information could be overlooked Other grey scales than the conventional linear one might therefore be of interest especially for hard copies of the image At the display console the operator has access to successive window settings for analysing the whole image

Two modified grey scales are presented For one (Grey 1) the objective was to leave the selected band unaffected but to compress the grey scale for the rest of the image so that with a small increase in width of the selected window the remaining parts of the image are also displayed albeit in a compressed grey scale For the other one (Grey 2) the number of pixels per grey scale interval was kept constant Extended regions of similar attenuation in the original image (e g the liver Figure) are then expanded i e displayed in a grey scale with an increased number of levels whereas boundary zones covering a small fraction of the attenuation level distribution in the image will be compressed Thus it is displayed with a reduced number of grey scale levels Another modification of the grey scale with a somewhat different purpose has been described by BORLAZA et coll (1978)

Material

The equipment consisted of an Ohio Nuclear Delta 50 FS with a 256×256 reconstruction matrix PDP 11 computers were available for program development and computations off line the scanner equipment The programs were written in Fortran with a special I/O system (TICS Task I/O Control System supplied by Uppsala Data Centre HOGSTROM 1978) The new programs were run under operating system RT 11 whereas the scanner programs were run under DOS (both supplied by Digital Equipment)

Methods

Grey 1 The operator decides the lower (Min) and upper (Max) Hounsfield numbers of the window from viewing the original image and settles a compression factor (Fact) The original image matrix is then read line by line by the program and a processed image created Pixels within the window (Min to Max) are transferred without change and pixels with a content (Cont) less than Min are replaced by Min−(Min−Cont)/Fact where Fact is restricted to 2 4 8 16 32 or 64 to allow integer arithmetics Analogously pixels with a content above Max are replaced by Max+(Cont−Max)/Fact

Grey 2 The operator after deciding a lower (Min) and an upper (Max) limit for the pixels to be processed starts the program to sort these pixels in a histogram with 1000 consecutive classes of equal width New class boundaries are then selected so that each new class contains 1/256 of the number of pixels within the window Next the original image is searched a second time and the pixels assigned new values on the 256 class scale

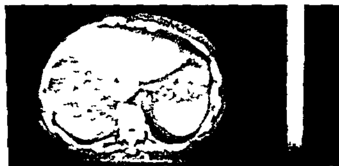
Submitted for publication 26 March 1979



a



b



c



d



e



f

Original tomograms at window widths of a) 1 002 and b) 171 Hn c) *Image processed with Grey 1* (Min 24 Max 74 Hn Fact 8) d) Image processed with Grey 2 (Min −170 Max +670 Hn) e) Histogram of the original image f) Histogram of the Grey 2 image

Results

The original image from a patient with a liver tumour is displayed in the Figure With a window of 1 002 Hn (Figure a) the contours of the body and the bony and soft tissue structures are visible but not the tumour At a window of 171 Hn (Figure b) the tumour is visible as a darker region in the posterior part of the right liver lobe while the bony structures and the rest of the liver appear white The contour of the body is not visible When the image is processed with Grey 1 the unaffected window region in the *liver with the tumour* is visible and outside this the contour of the body in the compressed grey scale at the same window level as in Figure b 171 Hn (Figure c) At a window level of +49 Hn and a width of 50 Hn (range +24 to +74) the tumour is displayed with high contrast

With Grey 2 a window setting of 1 002 Hn displays simultaneously the contour of the body and the liver tumour (Figure d) The extension of the scale in Grey 2 is illustrated by the histograms of the original (Figure e) and processed (Figure f) images

Discussion

A disadvantage of Grey 2 is that the attenuation of the object cannot be evaluated from the processed image with Grey 1 this applies only for pixels outside the selected window Such measurements thus require reference to the original tomogram

The two methods of grey scale modification dem strate that alternatives to the conventional linear play may be found that might be better suited for ostic work They may also be of value in dem strating images to an audience as the contours the body as well as the lesion in an internal organ e displayed in the same image Also for hard copy umentation the modified CT images are of in rest as they convey more information than the onventional ones displayed either with extended or arrow windows

SUMMARY

Optimum perception of minute but relevant attenuation fferences in CT images often requires display window ttings so narrow that a considerable fraction of the im ge appears completely black or white and consequently ithout structure In order to improve the display charac ristics two principles of grey scale modification are pre nted In one method the pixel contents are displayed nchanged within a selectable attenuation band but moved owards the limits of the band for pixels that are outside it n the other the grey scale is arranged to a constant umber of pixels per grey scale interval

ACKNOWLEDGEMENT

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DIAGNOSIS

1980

COMPLICATIONS OF ANGIOGRAPHY IN CHILDREN AND MEANS OF PREVENTION

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The frequency of local thrombotic and distal rromboembolic phenomena occurring during per utaneous angiography has been widely evaluated epending on the method of evaluation the fre uency varies from 0 to more than 50 per cent but linically significant occlusions are usually reported o occur in 0 2 to 3 0 per cent of cases Children ave been considered to be in a high risk group specially young infants (for review see MOR ENSSON et coll 1976) This as well as the difficulty f performing percutaneous arterial puncture has aused some centers to limit the use of angiography n small children This report is a prospective valuation of 267 consecutive angiographies per ormed at this hospital over an eight year period Oscillography was used to detect any pulse decrease eflecting either spasm or thrombosis As more in ormation about the etiology of thrombosis in con nection with catheterization has become available he technique was modified with a subsequent drop n complications As multiple factors were changed at different times no statistical analysis can be made as to which specific change was mainly responsible for the decrease in the complication rate The mod ifications are described together with the reasons for their introduction

Materials and Methods

The series consisted of 267 consecutive trans femoral angiographic examinations performed be tween 1970 and 1977 the majority being abdominal and the remainder including examinations of ex tremities skull and heart During the interval be tween 1970 and 1974 angiography was performed in 14 infants (under 2 years of age) via surgical expo sure either because of expected difficulties in per cutaneous puncture in a small child or failure with the percutaneous technique Since 1974 the per cutaneous technique has been used exclusively and in only one instance was it impossible to catheterize the vessel The ages of the infants and children examined by the percutaneous technique were be tween newborn and 16 years 26 were less than one year 58 between one and 5 years 68 between 5 and 10 years and 101 were 10 years or older The number of examinations per year has increased par ticularly in the group under 5 years of age (Fig 1) Selective catheterizations have also increased Lo cal anesthesia was usually used during 1970 to 1973 thereafter general anesthesia in most patients Radiologists with varying experience performed the examinations The puncture site was compressed for approximately 10 min following the procedure care being taken to maintain the distal pulse during compression

Oscillography was carried out with a Gessenius Keller oscillograph before the examination and re peated following the procedure as soon as hemo stasis was achieved for detecting obstructive vascu lar complications If the maximum excursion dif fered in the two legs by more than 3 mm it was considered significant When the maximum excur sion on either side was less than 6 mm and the value on the catheterized side was less than half that of the uncatheterized side circulation was also considered impaired (JACOBSSON et coll 1973) The oscillo

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graphy was repeated during the next 4 hours if the circulaton was abnormal immediately after the examination Persistence of an abnormal value for 4 hours was used as the criterion for vascular obstruction and appropriate measures were taken A return to normal within 4 hours indicated a transient decrease in pulse and no treatment was required

In an effort to improve the safety of the catheterization several technical changes have been made aimed mainly at limiting the formation of thrombus on the catheter surface Several different types of catheter were used until four years ago Since then only the Radicath set for angiography in children (Becton & Dickinson U S A) has been used These catheters are extremely thin walled giving a maximum inner diameter while minimizing the outer diameter This set includes a puncture needle and guide wire adapted to the catheters

Systemic heparinization was included in the procedure during early 1976 (75 units/kg body weight) Heparinization of the catheter itself was however considered preferable and when such catheters became available in 1976 they were used instead of systemic heparinization The catheters were heparinized by the process described by ERIKSSON et coll (1967) During the last three years thrombectomy has been performed with a modification of the method described by JEFFERY (1972) By this method blood is aspirated at the very moment when the tip of the catheter is leaving the lumen of the artery during simultaneous compression just distal to the puncture track and blood is allowed to spurt out for a moment Thrombi if any around the puncture site may then either be aspirated into the catheter or washed out

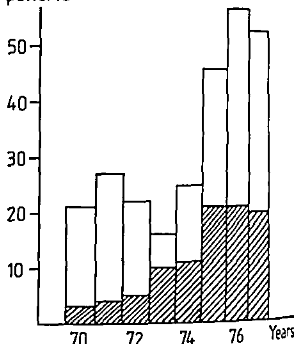


Fig 1 Number of examinations between 19 0 and 19 The number of children under 5 years is indicated with striped bars

Results

Complications due to the formation of thrombus occurred in 14 cases 8 of them (57%) in 14 exposed arteries and 6 in the 253 percutaneous approaches (2 4% Fig 2) In all cases in which surgery was performed (9) and in the one case that underwent repeat angiography the diagnosis of thrombus formation and occlusion could be confirmed In the percutaneous group (Fig 3) 3 complications occurred in the 75 patients under 5 years of age (4%) none of these in the 26 patients under one year of age Two complications occurred in the 5 to 10-year group (3 3%) and one complication in the group 10 years and older (1%) No complications have been encountered in the last 3 1/2 years i e the last 153 examinations have been without significant morbidity The decreasing complication rate is significant ($p<0.02$) No significant change in the frequency of transient decrease in pulse was found when the group examined before 1974 was compared with the group after 1974 Whether general or local anesthesia was used did not influence the frequency of a transient decrease but did increase with decreasing age of the child (Fig 4)

The thromboembolic complication rate was not related to any specific catheter or type of examination No complication has occurred since the introduction of systemic heparinization of the patient in the procedure or with use of heparinized catheters Prolonged bleeding after withdrawal of heparinized catheters has previously been observed (FLODH & JACOBSSON 1974) but this caused no difficulty in the present series Of the cases with complications in the percutaneous group 5 underwent routine Fogarty thrombectomy within 10 hours Thrombosis at the puncture site was found in all 5 In the sixth patient the oscillography was abnormal in the lower leg but not in the thigh following the examination At repeat angiography the same day an embolism in the popliteal artery was demonstrated and the child was treated with heparin The treatment of co

Examinations
267
Surgical exposure
14
Percutaneous
253
Transient de crease in pulse
1
8
6
Transient de-crease in pulse
48
Thromboembolic complications
6
No significant complication
247
No significant complication

ig 2 Number of femoral artery catheterizations for angiography tween 1970 and 1977 and complications from the procedure

ations and their long term results have been de ribed in another report (RUBENSON et coll 1979)

Discussion

Th frequency of complications associated with he surgical exposure was found to be much higher than with the percutaneous approach and was considered to be unacceptable This technique was therefore abandoned With increasing experience with the percutaneous approach the femoral artery was catheterized in all children during the past 3 1/2 years with one exception

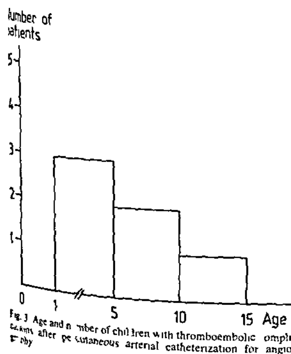


Fig 3 Age and number of children with thromboembolic compli cations after percutaneous arterial catheterization for angio-graphy

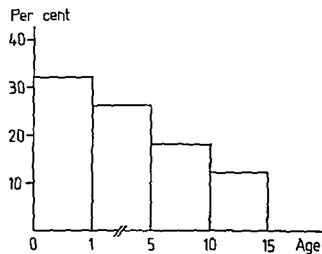


Fig 4 Frequency of children with transient decrease of pulse after percutaneous femoral artery catheterization for angiography

The variation in the reported frequency of complications is partly due to variation in the method of detecting these complications Methods of detection include clinical signs of decreased blood supply and pulse evaluation which rely on subjective estimations The more objective methods include oscillography (REAL et coll 1966 WHITE et coll 1968 HOHN et coll 1969 JACOBSSON & SCHLOSSMAN 1969) plethysmography (MORTENSSON et coll 1975) Doppler evaluation (BARNES et coll 1977) routine Fogarty thrombectomy (BAKER et coll 1968) and pull out angiography (SIEGELMAN et coll 1968 FORMANEK et coll 1970) Using this last mentioned method small amounts of thrombus on the catheter are detected which may or may not result in a significant occlusion The oscillographic method used objectively evaluates the pulses in the lower leg but cannot detect smaller thromboemboli in the more distal arteries of the foot Although wide variance in complication rates have been reported the frequency in adults most often lies between 0 2 and 3 0 per cent Younger patients are considered to be at greater risk In the present series the overall rate is 2 4 per cent in children with a tendency to a slightly higher risk in the age group under 5 years (4%) but no special predilection for infants under one year However the results also show the possibility of significantly reducing the complications thus the last 153 examinations were uneventful

The decreased complication rate during recent years appears to be attributable to technical changes in response to growing evidence that the major factor in local thrombotic and distal thromboembolic complications is the formation of the thrombus on the catheter surface with subsequent stripping off of this thrombus as the catheter is pulled back through the wall of the artery (NEJAD et coll 1968 JACOBSSON 1969) The number of thrombi can be minimized first by using thin walled catheters resulting in a decreased surface area available for formation of thrombus Secondly heparin inhibits the formation of thrombus Systemic heparinization has been shown to decrease the rate of thrombotic complications (WALLACE et coll 1972 ANDERSON et coll 1974 KAPLAN et coll 1975) but this carries with it the inherent risks of anticoagulation Localized high concentration of heparin at the blood catheter interface can be accomplished by coating the catheter with heparin obviating the necessity for systemic heparin with its potential problems (ERIKSSON et coll JACOBSSON & SCHLOSSMAN 1973 ELDH & JACOBSSON) Stability of the heparin coating has been a problem with thrombogenicity increasing during the course of th examination (WHIFFEN & BEECKLER 1966) The heparinization method of ERIKSSON et coll provides a coating shown to be stable for many hours and even days in contact with blood (HEIDEMAN et coll 1976 OLSSON et coll 1977)

The thrombectomy as described by JEFFERY is an attempt to flush out any thrombus which may have been stripped from the catheter and remains at th site of puncture

No other changes have been made which would account for this recent decrease in complications The number of selective examinations and catheter exchanges has increased as has the number of smaller children The recent examinations have been performed by radiologists with varying ex perience including some doing their training in pediatric radiography

Transient changes in pulse are thought to repr sent spasm as rapid collateral reconstitution would presumably not result in immediate return of equal pulse bilaterally The frequency of this spasm h s not decreased during these years indicating that the local trauma at the site of puncture has not di minished This would support the contention that the present decrease in complication rate is a result of the decreased thrombus formation on the catheter itself rather than local factors at the site of puncture

It seems reasonable to conclude that angiography can be performed in infants and children via the percutaneous approach with a high success rate and if proper measures are taken with a low complica tion rate

SUMMARY

In 267 consecutive angiographic examinations in ch dren 14 thromboembolic complications occurred [illegible] ing surgical exposure 8 complications in 14 ca es and [illegible] complications in 253 percutaneous angiographies The origin of thrombus during angiography has recently be clarified Technical advances such as thin walled ca ters systemic heparinization and lately heparinized ca ters decreased the complication rate significantly n com plication occurred among the last 153 examination

This investigation was carried out while one of the a thors (H C) was on leave from the Departmen of Radiology Presbyterian University Hospital P [illegible] Pennsylvania 15213 U S A

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METRIZAMIDE AND METRIZOATE FOR CARDIOANGIOGRAPHY IN INFANTS

Comparison of heart rate and arrhythmia

M HELLSTROM B JACOBSSON S E SORENSEN and B O ERIKSSON

Although new and non invasive methods for ex ination of children with congenital heart disease e been introduced such as scintigraphy and rasound cardioangiography still has to be in ded in the preoperative examination of these ldren in most cases

Serious side effects of cardiac catheterization and giographic procedures appear to be unavoidable present The hazards are particularly great in onates and infants especially in children with mplex cardiac malformations (HO et coll 1972 ROVETZ et coll 1968 MCINTOSH 1968) Mortality es as high as 12 8 per cent in infants less than one onth of age have been reported by HO et coll ile the overall mortality in children up to 15 years age in the same series was 1 5 per cent

Complications are mainly considered to be due to anipulation of the catheter (GRAINGER 1965 HO et ll KROVETZ et coll) and to a lesser extent to the ntrast medium (GRAINGER SWAN 1968) How er the mortality rate has been shown to be influ ced by the choice of contrast medium (HO et oll)

Experiments have indicated that the non ionic ontrast medium metrizamide is less cardiotoxic an other contrast media in common use for ardioangiography Thus ALMEN (1973) demon rated that metrizamide caused less fall in blood ressure and less bradycardia when injected in the ortic bulb in cats compared with diatrizoate (An iografin) and metrizoate (Isopaque Cerebral) In nimal experiments ALMEN & ASPELIN (1975) found that metrizamide caused less reduction in ventricu lar contractile force and heart rate less rise in pulmonary artery pressure and also less injury to the aortic endothelium than various ionic contrast media

TRAGÅRDH et coll (1975) and HIGGINS & SCHMIDT (1978) demonstrated in coronary an giographies in the dog that metrizamide produces less alteration in cardiac functions than other com monly used contrast media Following injection of metrizamide diatrizoate and metrizoate into the right coronary artery of dogs TRAGÅRDH & LYNCH (1978) found a lower incidence of ventricular fibrilla tion after the injection of metrizamide compared with diatrizoate

Metrizamide has also been used clinically for coronary angiography by ENGE et coll (1977) who reported less decrease in diastolic blood pressure compared with metrizoate (Isopaque Coronar)

Therefore it seemed to be of value to find out whether the findings mentioned are also valid in the high risk group of neonates and small infants sub jected to cardioangiography

Material and Methods

The material consisted of 52 infants examined by cardiac catheterization and cardioangiography The infants were investigated at the Children s Hospital in Gothenburg during 1976 to 1978 because of con

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Table 1

Comparison between the two groups of patients injected with either Isopaque Coronar or Amipaque LA = left atrium LV left ventricle RV = right ventricle

	No of patients	Mean weight (kg)	No of injections	Injection site			Contrast medium	
				LA	LV	RV	Mean dose (ml/kg/inj)	Mean flow rate (ml/s)
Isopaque Coronar	28	3 8	37	5	15	17	1 9	6 5
Amipaque	24	3 3	37	5	15	17	2 1	5 9

genital heart disease which were usually complex in nature The ages ranged from less than one day to eight months and 62 per cent of the infants were neonates Most of the children had serious cardiac symptoms

The patients were not randomized but represented consecutive examinations including only children with a weight of less than 5 kg The contrast media used were Isopaque Coronar (metrizoate 370 mg I/ml) and Amipaque (metrizamide 370 mg I/ml) The age weight and general condition of the children did not influence the choice of contrast medium The same contrast medium was always used for repeated injections

The Cisal II injector used did not allow the flow rate to be preset Catheters of slightly varying length and diameter were used Amipaque has a higher viscosity than Isopaque Coronar and this may result in somewhat varying injection rates Only consecutive Isopaque Coronar examinations with flow rates as close as possible to those in the Amipaque group were selected for evaluation in order to make the two groups as equal as possible

Premedication was given to 10 children who received either a combination of pentazocine and diazepam or a combination of pethidine promethazine and chlorpromazine All patients were examined by cardiac catheterization and angiography in the same session The catheters were inserted through the femoral vein after local anesthesia with lidocaine 0 5 per cent without epinephrine Cardiac catheterization was performed with heparinized Cook s catheter No 5 or 6 using a catheter with an occluded tip for angiography Heparin (50–100 IU/kg body weight) was injected through the catheter immediately after its insertion in all except 6 cases

Twenty eight children were examined with Isopaque Coronar with a total number of 37 contrast medium injections 24 patients with Amipaque also with a total number of 37 injections Five injections were made in the left atrium 15 in the left ventricle and 17 in the right ventricle respectively (Table 1)

The mean weight of the children who received Isopaque Coronar was 3 8 kg (range 2 7–5 0 kg) The mean amount of contrast medium injected each time was 1 9 ml/kg body weight (range 1 5–2 6 ml/kg The average flow rate of medium was 6 5 ml/s (range 5 0–8 9 ml/s Table 1)

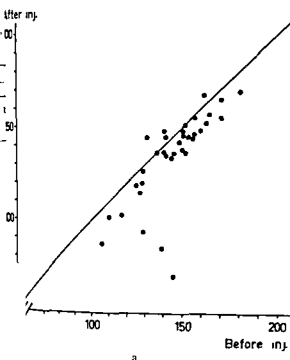
The mean weight of the children who received Amipaque injections was 3 3 kg (range 2 0–5 0 kg) The mean amount of medium injected each time was 2 1 ml/kg body weight (range 1 4–2 8 ml/kg) The average flow rate was 5 9 ml/s (range 3 5–10 0 ml/s Table 1)

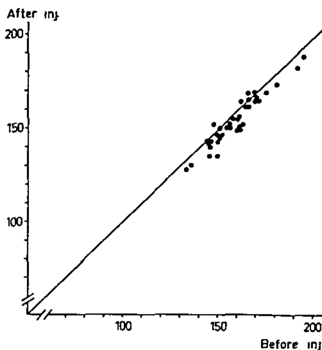
The injection time was automatically recorded by the Cisal II injector ECG standard lead II as well as the contrast injections were recorded on an 8 channel Mingograf during the examinations The recordings were continued for at least 10 seconds after the start of the contrast injections

The occurrence type and timing of immediate extrasystoles as well as change in heart frequency were recorded for each injection

A change in frequency exceeding the variation during an observation period of 3 seconds before the injection was regarded as tachycardia or bradycardia The maximum change of frequency and its timing in relation to the start of contrast injection were estimated Heart frequency was measured on 3 consecutive cardiac cycles using R R intervals

Statistical evaluation Proportions were compared by use of Fisher s exact test The general permutation test of Fisher (ODÉN & WEDEL 19[illegible]) was used to compare the change of cardiac frequency between the Isopaque Coronar group and the Amipaque group All p-values concern two-sided tests





...um change in heart rate within 10 s after injection of a) ...ue Coronar (370 mg I/ml) and b) Amipaque (370 mg I/ml)

Results

...e image quality was similar in the examinations ...rmed with the two contrast media but no ...matic evaluation was done in this respect Most ...ts showed signs of discomfort and jerked during ...njection of Isopaque Coronar This was rarely ...rved when Amipaque was employed

...rdiac frequency A decrease in frequency after ...tion of Isopaque Coronar as well as after Ami...e was usually observed but no change occurred ...r 6 injections of Isopaque Coronar and after 8 ...paque injections Bradycardia was registered in ...f 37 injections of Isopaque Coronar (22 of 28 ...ents) and in 26 of 37 injections of Amipaque (18 ...5 patients Figure) The decrease in heart rate ...significantly greater (p<0 01) following injec... of Isopaque Coronar (14 6 beats/min) than after ...ction of Amipaque (6 1 beats/min Table 2) The ...imum fall in heart rate was 70 beats/min (from ... to 70 beats/min) after Isopaque Coronar and 14 ...ts/min after Amipaque The maximum decrease ...heart rate occurred at approximately the same ...e 6 ? and 5 6 s respectively after the start of ...ction A very moderate increase in heart rate ...s observed in 7 examinations 4 following the ...ction of Isopaque Coronar and 3 following the ...ction of Amipaque

Cardiac rhythm Extrasystoles during or in immediate connection to the contrast injection were recorded in 21 of 37 (57%) examinations (19 of 28 patients) using Isopaque Coronar and in 9 of 37 (24%) examinations (9 of 24 patients) using Amipaque This difference is significant (p<0 01 Table 3) A series of two or more extrasystoles (coupling) occurred after 13 injections (35%) of Isopaque Coronar and after 3 injections (8%) of Amipaque (p<0 01 Table 3) The majority of extrasystoles were of ventricular origin but in 4 instances of supraventricular origin The extrasystoles occurred after a mean time of 0 7 s using Isopaque Coronar and after 0 9 s using Amipaque The extrasystoles occurred at the same time in relation to the injection irrespective of the injection site 0 8 s after the start of injection in the right ventricle and 0 7 s after the start of injection in the left ventricle No significant difference in arrhythmia production between right and left ventricular injections could be demonstrated No difference in mean flow rate was found between injections giving rise to extrasystoles compared with injections not causing extrasystoles 6 3 ml/s and 6 2 ml/s respectively There was no correlation between the dose of contrast medium and the occurrence of extrasystoles However variation in dose was very moderate

Table 2

Magnitude of bradycardia within 10 seconds after injection of contrast medium

	Heart rate (beats/min)				Time (s) after start of injection
	Before	After	Difference	Maximum difference	
Isopaque Coronar	145 1	130 5	14 6	70	6 2
Amipaque	159 1	153 0	6 1	14	5 6

The difference between Isopaque Coronar group and Amipaque group is significant (p<0 01)

Table 3

Incidence and occurrence of extrasystoles during and immediately after injection of contrast medium

	No of injections	Extrasystoles	Time (s) after start of injection	Coupling
Isopaque Coronar	37	21/37 (57%)	0 7	3/37 (35%)
Amipaque	37	9/37 (24%)*	0 9	3/37 (8%)

Discussion

The two groups of patients were well comparable regarding diagnosis age weight premedication injection site dose and flow rate

Bradycardia is well known to occur in cardioangiography and can be mediated via several mechanisms One of these is due to the effect of the contrast medium on the coronary circulation either by direct depression of sinus node activity ECKBERG et coll 1974 HIGGINS 1977) or by activation of coronary baroreflexes or chemoreflexes (ECKBERG et coll) In animals receptors in the heart have been found giving rise to bradycardia through vagally mediated reflexes when stimulated (ROMERO et coll 1977) A similar mechanism has been suggested by FRINK et coll (1975) to be partly responsible for the bradycardia observed during coronary angiography in man Bradycardia may also be mediated by the influence of contrast medium on the brain (LUNDERVOLD & ENGFSET 1967)

In the present series bradycardia was regularly registered more marked after Isopaque Coronar (14 6 beats/min) than after Amipaque (6 1 beats/min) The most serious bradycardia occurred after an injection of Isopaque Coronar with a fall in heart rate from 140 to 70 beats/min The most marked decrease in heart rate after injection of Amipaque was from 149 to 135 beats/min Previously it has been demonstrated in experimental animals that metrizamide causes less inhibition of sinoatrial automaticity (HIGGINS) and less bradycardia (ALMÉN) than other commonly used contrast media The present clinical findings correspond with these experiments

Arrhythmias during or in close relation to contrast medium injections were frequently registered in the present series Extrasystoles occurred more than twice as often after injection of Isopaque Coronar as after injection of Amipaque and series of extrasystoles occurred more than four times as often after Isopaque Coronar It seems reasonable to assume that series of extrasystoles are potentially more dangerous than single ones Arrhythmias during cardioangiography may be caused by the influence of the contrast medium in the coronary circulation either by inhibition of the conducting system or by a direct effect on the myocardial cells (HIGGINS TRAGÅRDH & LYNCH TRAGÅRDH et coll 1974) In the present series the extrasystoles occurred within one second after the start of injection regardless of whether this was performed in the right or left ventricle In most cases this reasonably excludes a triggering by the coronary circulation Thus most of the extrasystoles can be assumed to be caused by a direct local effect on the endo-myocardium either of mechanical or chemical origin It is well known that manipulation of the catheter in the heart can mechanically induce extrasystoles (MCINTOSH

VENABLES & HILLER 1963). During injection the catheter recoil as well as the contrast jet (KROVETZ et coll. 1967) may also mechanically trigger extrasystoles. Amipaque is more viscous than Isopaque Coronar. When fluids of different viscosity are injected at similar flow rates the catheter recoil effect will be the same, but the difference in viscosity may cause varying jet effects. However, this difference is probably of minor practical importance. Thus, the less frequent occurrence of extrasystoles in the Amipaque group does not seem to be explained by mechanical factors. This suggests that at least some of the extrasystoles are caused by physical/chemical influence of the contrast medium locally on the endo-myocardium. Similar findings were reported by REFSUM & PASSWAL (1978), who observed an arrhythmogenic effect of contrast media in direct contact with isolated rat atria. In those experiments metrizamide caused less arrhythmia than metrizoate and diatrizoate.

The results of the present clinical investigation agree with previous experimental and clinical reports indicating that Amipaque is less cardiotoxic than other commonly employed contrast media for cardioangiography. It seems reasonable to assume that the differences between Amipaque and Isopaque Coronar are of clinical importance, especially in the examination of neonates and small infants in a bad general condition and with complicated congenital cardiac disorders.

SUMMARY

The cardiotoxic effect of Isopaque Coronar (metrizoate 370 mg I/ml) and Amipaque (metrizamide 370 mg I/ml) was analysed in 57 infants weighing less than 5 kg. In each group of patients 37 injections of contrast medium were performed and the immediate side effects, extrasystoles and change in heart frequency, were recorded. Amipaque caused significantly less bradycardia and significantly fewer immediate extrasystoles than Isopaque Coronar. The results indicate a lower cardiotoxicity of Amipaque in cardioangiography in infants.

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VARIATIONS IN VESICOURETERAL REFLUX

Influence on diagnostic validity

S LAURIN and W MORTENSSON

In children with vesicoureteral reflux repeat mic-urition cystourethrography is usually performed Therefore every possible measure to reduce radia-tion dose should be seriously considered One method is to reduce the number of films at each examination However the inconstant nature of re-flux may cause the diagnostic information to be dis-torted or incomplete

The aim of the present investigation was to evaluate the risk of missing or underrating a ves-icoureteral reflux at micturition cystourethrography when the number of exposures was reduced

Material and Methods

The analysis was based on 465 micturition cys-tourethrographies performed in an equivalent number of infants and children aged 0 to 12 years mean 4 6 years Seven duplex kidneys had complete ureteral duplication thus the competence of the ureteral orifices was evaluated in a total of 937 in-stances All patients were examined because of uri-nary tract infection Patients with neurogenic blad-der diseases or urethral obstruction were excluded

At micturition cystourethrography the bladder was slowly filled with contrast medium (Isopaque Cysto Nyegaard Norway) by means of drip infu-sion till the patient needed to void One film cover-ing the whole urinary tract was exposed before mic-turition The catheter was then withdrawn and two or more films were exposed during forceful micturi-tion In the individual case it was considered how many films would be necessary in order to obtain adequate information The general intention was to keep the number of exposures low Finally one film was exposed immediately after completed mic-turition to demonstrate a possible end micturition reflux In order to obtain an opinion of irregularity of the pre micturition reflux three films were exposed instead of one while filling the bladder in 162 of the patients with together 327 ureters One film was exposed when the bladder was filled to one third and two thirds respectively of the calculated capacity estimated with regard to the age of the patient The third film was exposed when the bladder was filled to tolerance Fluoroscopy was not used

The refluxes were classified as Grade 1 when con-trast medium ascended into the ureter only as Grade 2 when the contrast medium reached the renal pelvis and as Grade 3 when in addition the pelvis became distended as compared with its size at uro-graphy performed with compression of the ureters Variations of the reflux within these classes were left without notice

The maximum reflux demonstrated in a ureter was considered to represent the true degree of reflux for that ureter irrespective of the examina-tion phase in which it appeared Any deviation from this degree of reflux on any of the other films thus constituted a risk of erroneous diagnosis the magni-tude of this risk was calculated from the frequency of films demonstrating such deviations

The probability of missing or underrating reflux of a certain degree was calculated in relation to the

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Table 1

Frequency of vesicoureteral reflux in 937 ureters

	No of ureters	Per cent of all ureters	Per cent of all reflux ureters
Isolated pre micturition reflux	10	1 1	5 9
Micturition reflux	156	16 7	92 9
Isolated end micturition		0 2	1 2
Total	168	18 0	100 0

Preceded by pre micturition reflux in approximately 80 per cent of cases

Table 2

Number [illegible] films micturition in 9 children with [illegible] reflux into 10 ureters

Pre micturitions	No of exposures during micturition	
	2	3
Grade 1	2	4
Grade 2	1	3
Total	3	7

Table 3

Degree and constancy of vesicoureteral reflux during micturition related to number of films exposed during micturition

	No of exposures during micturition				Total No of ureters
	2	3	4	5-6	
Constant grade of reflux					
Grade 0	217	471	89	4	781
Grade 1	1	1	0	0	[illegible]
Grade 2	55	30	[illegible]	1	88
Grade 3	11	16	5	[illegible]	34
Total	284	518	96	7	905
Varying grade of reflux					
Grade 0 to 1	4	5	0	0	9
Grade 0 to 2	7	7	5	0	19
Grade 0 to 3	0	0	0	0	0
Grade 1 to 2	[illegible]	1	0	0	3
Grade 1 to 3	0	0	0	0	0
Grade 2 to 3	1	0	0	0	1
Total	14	13	5	0	[illegible]
Per cent with micturition reflux	27	11	17	43	
Per cent with varying micturition reflux	5	[illegible]	5	0	

actual number of ureters with this particular degree of reflux Such calculations were not influenced by the relative frequency of refluxing ureters in the total material

The probability of missing or underrating a reflux was calculated for the following hypothetical alternatives (1) only one film exposed and this during micturition (2) one film exposed after the bladder was filled and another during micturition (3) as in (2) plus a third film exposed immediately after micturition was completed and (4) as in (3) but two films exposed during micturition

Results

Vesicoureteral reflux occurred in 168 of the 937 ureters examined (18% Table 1)

Micturition reflux was the most common type but it was usually preceded by pre micturition reflux In patients with reflux before as well as during voiding the pre micturition reflux did not exceed the micturition reflux in any instance

Isolated pre micturition reflux appeared in 10 ureters (9 children) The grade of the refluxes and the number of films exposed during the subsequent micturition are given in Table 2 The frequency of isolated pre micturition reflux had no relation to the number of films exposed during the subsequent micturition (χ^2 test)

Isolated end micturition reflux appeared in 2 ureters (2 children) grades 2 and 3 respectively 4 films had been exposed during the forceful micturition phase in both cases

The frequency and severity of the micturition reflux varied in the films exposed during forceful micturition in every fifth ureter with micturition reflux (Table 3) Such variations did not become more frequent by increasing the number of films (χ^2 test)

In the minor group of 324 children examined with particular regard to the irregularity of the pre micturition reflux the 3 pre voiding films showed uniform conditions in 287 ureters In 30 ureters the reflux occurred first or was at a maximum on the third film In the remaining 10 ureters maximum reflux occurred on the first or second film (Table

Table 4

Maximum degree of reflux on the first 2 films and on the third film exposed during filling of bladder in cases with varying pre-micturition reflux

Maximum reflux first films	No. of ureters	Reflux on third film	No. of ureters
Grade 1	7	Grade 0	7
Grade 2	2	Grade 0	1
		Grade 1	1
Grade 3	1	Grade 2	1

Table 5

The probability that a vesicoureteral reflux of a certain degree will be missed or underrated at micturition cystourethrography performed according to the 4 alternatives

Reflux	Alt. 1	Alt. 2	Alt. 3	Alt. 4
Missed				
Grade 1	0 61	0 16	0 16	0 04
Grade 2	0 13	0 08	0 04	0 01
Grade 3	0 03	0 03	0 00	0 00
Total	0 77	0 27	0 20	0 05
Underrated				
Grade 2 judged as Grade 1	0 02	0 02	0 014	0 003
Grade 3 judged as Grade 1	0 014	0 014	0 014	0 000

Those 10 instances constituted a measure of the error of the present investigation in assessing the frequency and degree of pre-micturition reflux, as only the last of the 3 films was taken consistently and used to represent the whole pre-micturition phase.

The probability of missing or underrating a vesicoureteral reflux when the number of films was reduced according to the different examinational alternatives appears in Table 5.

Discussion

The presence of vesicoureteral reflux substantially increases the unfavourable effect of urinary tract infection on the renal parenchyma. This effect is positively related to the time of appearance and in particular to the degree of the reflux (KJELLBERG et coll. 1957, LATTIMER et coll. 1963, MORTENSSON & HELIN 1974, APERIA et coll. 1976, MANLEY et coll. 1976, RANSLEY 1976, VLATKOVIC et coll. 1976). Micturition cystourethrography should be designed to be a guide to treatment and prognosis with reasonable accuracy. Theoretically 3 films should suffice: one exposed before, one during and one immediately after completed micturition. However, the irregularity of the reflux renders it uncertain that the films actually represent the maximum possible reflux during each phase. Fluoroscopic monitoring, videotape recording or cinefluorography of the entire examination procedure has been recommended in order to exclude the risk of missing a transient reflux (GROSS & SANDERSON 1961, MELICK et coll. 1962, SHOPFNER 1965, GOULD & PETERSON 1966). However, attempts to increase diagnostic reliability must be weighed against the hazards of irradiation and the consequences of an incorrect diagnosis.

The vesicoureteral reflux occurred mainly during micturition. For some reason reflux may sometimes occur only before voiding or at the end of voiding. Major refluxes were likely to occur during all the phases of micturition cystography (RUDHE 1962) and also to have a fairly constant severity.

It cannot be ruled out that the examination technique may play a role and in some cases induce at least a slight transient false reflux. However, in the present investigation all observed refluxes were considered to be true.

A basis for the conclusions was the assumption that all potential refluxing ureters had actually been diagnosed. This assumption was no doubt reasonable considering the fact that no increase occurred in the frequency of clinically significant refluxes during micturition through increasing the number of exposures, neither increased the frequency of ureters with varying degrees of micturition reflux. As only one film was exposed before initiation of micturition, irregularity of pre-micturition reflux was the cause of 2 per cent of ureters with transient Grade 1 reflux escaping diagnosis. These circumstances may be left without consideration as such slight refluxes apparently do not cause injury to the renal parenchyma. However, an additional risk existed that Grade 2 refluxes may be missed. This risk was so small (=0 003) as to be considered negligible.

Variations in the degree of reflux occurred during micturition in 21 per cent of the ureters with micturition reflux. In one third of the cases it was a question of transient Grade 1 refluxes (Table 3).

Isolated reflux appearing first at end micturition was rare It has also been reported that vesicoureteral reflux may not appear until hours after micturition which must apparently have been incomplete (STEWARD 1953 GROSS & SANDERSON) The frequency of this phenomenon cannot be determined Such a reflux may be looked upon as a form of pre micturition reflux

The present results show that a very high reliability may be achieved in demonstrating clinically significant vesicoureteral refluxes even when only 3 or 4 films are exposed only 4 and one per cent respectively of the Grade 2 refluxes and no Grade 3 reflux would be missed However a slight risk of underrating Grade 3 refluxes (Table 5) was apparent

Only the probability that a reflux would be missed or underrated when various examinations were used has been discussed However in discussing the benefit to cost ratio from the point of view of radiation exposure all of the non refluxing ureters must also be considered Such a calculation will be influenced by the composition of the material the greater the number of cases with non refluxing ureters the less the risk of missing or underrating a reflux In the present series no reflux occurred in 83 per cent of the ureters this frequency corresponds fairly well with that usually mentioned in the literature It means for example that the risk of missing a Grade 2 reflux calculated in relation to the total number of ureters examined would be approximately 0 005 when examination alternative 3 is used

The results suggest that the element of irregularity in the nature of the vesicoureteral reflux should not lead to an unnecessarily large number of films This is in agreement with the findings of SMITH (1966) In a group of children examined with both cineradiography and full size spot films the frequency of reflux was only a few per cent higher at cineradiography than at examination with spot films In the latter case 2 films were exposed one before and one during micturition Unfortunately the degree of the irregular refluxes was not reported

The ordinary examination technique using full size films has several advantages the photographic quality is high an adequate survey of the entire urinary tract is obtained and the antero posterior beam direction utilizes the radiation protection the filled bladder offers to the gonads in girls (GUSTAFSSON & MORTENSSON unpublished data)

Isotope cystography allows for continuous imaging of the entire examination without additional increase in the radiation dose to the patient The dose is on the whole very low (CONWAY et coll 19[illegible] Using a small number of full size spot films as in alternatives 3 or 4 in combination with modern rare earth screens the doses can also be kept very low the measured gonad dose in girls who constitute the majority of the patients was insignificantly higher than the estimated dose from isotope cystography (GUSTAFSSON & MORTENSSON) However radiography affords more detailed information rendering the evaluation of reflux more exact

SUMMARY

Micturition cystourethrography was performed with varying numbers of films exposed and the probability of missing a vesicoureteral reflux or underrating its severity was calculated for each series It was concluded that a small number of exposures can give sufficiently accurate diagnosis

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SIZE OF THE UNAFFECTED KIDNEY IN CHILDREN WITH UNILATERAL HYDRONEPHROSIS

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Urography plays a primary role in detecting and controlling hydronephrosis It demonstrates the gross morphology of the kidney the collecting system and the amount of parenchyma and the concentration of contrast medium provides approximate information on the renal function In unilateral nephropathy the decrease in function may also be disclosed from the degree of compensatory enlargement of the healthy kidney (McCREIGHT & SULKIN 196? GOSS 1964 APERIA et coll 1976 WIKSTAD et coll 1979 animal experiments KAUFMAN et coll 1974)

The present investigation was performed on children with unilateral hydronephrosis in order to find out whether enlargement of the unaffected kidney would reveal decreased function of the hydronephrotic kidney before this was detectable from decreased excretion of contrast medium at urography

Material and Methods

The series comprised 32 infants and children (21 boys and 11 girls) with unilateral hydronephrosis due to pelvi ureteric obstruction The right kidney was affected in 9 cases and the left in 23 The age of the patients ranged from 10 days to 13 years the median being 6 years The presenting symptoms were palpable abdominal tumour (2 cases) pro teinuria (1 case) urinary tract infection (9 cases) and abdominal pains (20 cases) The series included no patient with a duplex kidney

The material was classified into 3 age groups because of the age related variations in the renal size index in the reference group

At urography 2 to 4 ml of Isopaque Cerebral (Nyegaard Norway) were given per kg body weight to the infants and small children and 1 to 2 ml per kg body weight to the older children Immediately following the injection one film was exposed over the kidneys Ureteral compression was then applied and 10 to 12 min later 2 films in different projections were exposed over the kidneys and finally a survey film of the whole urinary tract was exposed after the ureteral compression was relieved

Renal function was assessed by the capability of excreting contrast medium at urography Only patients in whom the function of the hydronephrotic kidney was estimated as normal (n=23) or possibly slightly reduced (n=9) were included in the series The extra and intrarenal parts of the pelvis including pelvic stems and calyces were moderately to markedly dilated in all cases but one the latter case had a moderate dilatation of the pelvic confluence only The function and the morphology of the contralateral non hydronephrotic kidney were normal in all cases Vesico ureteral reflux was not present in any patient

Renal size index was calculated as the ratio of the longest axis of the kidney to the distance from the upper border of the first lumbar vertebra to the lower border of the fourth multiplied by 100

The reference group was made up of infants and children without symptoms of renal disease had normal routine laboratory tests (density and protein content of the urine urinary sediment) and normal urography

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Table

Renal si e index for the non hydronephrotic kidneys in 32 chil dren with unilateral hydronephrosis and for a reference group Excretion of contrast medium in the hydronephrotic kidneys was estimated as normal (n=??) or possibly slightly reduced (n=9) n=number of kidneys

Age (years)	Examination group			Reference group			
	Mean	1 SD	n	Mean	1 SD	n	
0	118	7 9	3	112	8 5	33	NS
1–_	114	7 2	4	101	5 7	28	p<0 005
3–13	102	5 8	25	93	5 4	119	p<0 001

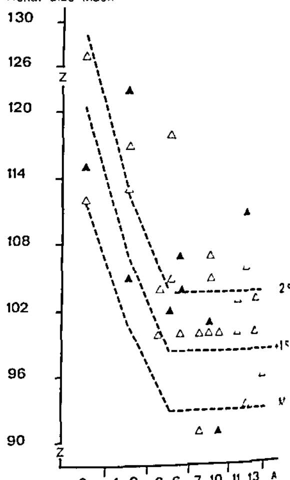
The significance tests were made according to Student s t test for unpaired observations

Results

No consistent difference in the renal size index of the healthy kidney was found between children with normal or possibly slightly reduced excretion of contrast medium in the hydronephrotic kidney (Fig)

The renal size index of the non hydronephrotic kidney was above the average in all cases but 3 in 10 cases the index was increased by more than 2 SD (Fig)

In each age group the mean value for the renal size index of the non hydronephrotic kidneys was higher than for the kidneys in the reference group (Table)



Renal size index for the healthy kidney in 3? children with uni lateral hydronephrosis The function of the hydronephrotic kid ney was normal in ?3 cases (Δ) and po sibly slightly decreased in 9 cases (▲) as estimated from urography The broken lines indicate mean value plus 1 and ? SD for a reference gro Age in years

Discussion

The compensatory enlargement of the mate kid ney in children with unilateral nephrectomy or nephropathy showed a high correlation between size and function the former being expressed as paren chymal area and the latter expressed in terms of glomerular filtration rate and some tests on tubular re absorption capacity (APERIA et coll 1977 1978 WIKSTAD et coll 1979) However for the sake of simplicity the length of the kidney was used instead of the area as a parameter of the renal size and function This was also indicated by the findings of JORULF et coll (1978) that the correlation between the height of L1-L3 and the renal parenchymal area and the renal length respectively was almost iden tical

The contrast medium used for urography is elimi nated by glomerular filtration and concentrated by the tubular water reabsorption (SAXTON 1969) The attenuation of the medium within the renal pelvis is dependent also on other factors i e the dose of the medium administered size of diuresis dilution by retained urine in the obstructed pelvis and the size of the pelvis Previously it has been demonstrated that renal function may be decreased although the excretion of contrast medium into a pelvis of reg lar size was apparently normal (HAMBY et coll 19? WILKIEMEYER & BOYCE 1972)

The mechanism initiating compensatory renal hypertrophy is not clearly understood for d sc sion of this phenomenon the reader is referred t ALLEN (1974) and EITMANN et coll (197?) I creased blood flow to the healthy kidney and in creased work load especially due to the selective re absorption in the tubuli seem to be the pri factors in eliciting renal hypertrophy while ot

ncreasing age and renal diseases impede the com ensatory response The hypertrophy involves mainly the renal cortex and both tubular and glomer ular function will increase (APERIA et coll 1977)

The enlargement of the unaffected kidney in the resent series indicated that reduced function of the ydronephrotic kidney was common although not isclosed by reduced concentration of the excreted ontrast medium in the pelvis The size of the ealthy kidney thus provided complementary infor mation on the condition of the diseased kidney The relation between the degree of functional decrease of the hydronephrotic kidney and the degree of the ompensatory enlargement of the mate kidney was not analysed In 2 infants with no visible excretion of contrast medium on the side of the hydronephro tic kidney and therefore not included in the series the renal size index was around 140 Corrected for the different measuring techniques used this cor responded to the maximum increase in parenchymal area of the healthy kidney which was observed in children operated upon with unilateral nephrectomy durin infancy (APERIA et coll 1977) Previously it has been pointed out by HODSON & CRAVEN (1966) that the unaffected kidney may be larger than the diseased kidney in adults with unilateral hydro nephrosis

SUMMARY

Children with unilateral hydronephrosis but without evidently decreased excretion of urographic contrast me dium generally had enlargement of the unaffected mate kidney indicating reduced function of the hydronephrotic kidney

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ARTHROGRAPHY OF THE HIP IN CHILDREN

Technique normal anatomy and findings in unstable hip joints

T LÖNNERHOLM

Clinical signs of a congenital or acquired abnor lity in one or both joints in a child generally leads radiographic examination of the pelvis and hips e most common indication for this examination in eden during the first year of life is probably con ntal idiopathic hip instability ANDRÉN & VON SEN (1958) have described how the radiographic amination should most suitably be performed for gnosing this condition in the first days of life

Conventional films of the hip in children espe lly young infants give limited information on the atomy of the joint as they only allow evaluation the mineralized parts The relation of the femoral ad to the acetabulum may be difficult to assess pecially when the femoral head is not mineralized all The difficulties encountered in the radio- aphic diagnosis of hip disorders are reflected by e large number of different methods that have en described for measurement of distances and gles on the films The main purpose of these ethods is to establish the relative position of the moral head with greater certainty The difficulties t seldom lead to poorly founded diagnoses which y result in an unnecessarily large number of fur er radiographic examinations and may also have a gative influence on the choice of treatment

Wh n information on the non mineralized compo- nts of the joint is required arthrography must be sorted to

As early as in the 1920 s arthrography of the hip as performed on a smaller number of children th the use of iodipin an oily contrast medium EVERS 1927) or air (BRONNER 1927) but it was t until the aqueous iodine contrast media were introduced in the 1930 s that hip arthrography gained more general application On the basis of arthro- graphies performed post mortem on children with normal hips FABER (1938) and SEVERIN (1941) established criteria for the normal appearance which still seem to be generally accepted (e g LAURENT 1953 GRECH 1977) An early diagnosis of congenital idiopathic hip instability was at that time uncommon and their clinical material therefore mainly comprised children who had already began to walk The same is also true for a large Finnish series (LAURENT) The investigations of coxa plana (Perthes disease) by JONSATER (1953) included arthrography of the hip

A small number of arthrographies on newborn infants with hip instability have been reported by PALMEN (1961) and FELLANDER et coll (1970) Otherwise no Scandinavian series of arthrography appear to have been published in the last 25 years One reason for this is the diminished need for this examination mainly due to the present possibility of diagnosing congenital idiopathic hip instability at a very early stage The number of arthrographies per formed today is small even in large departments of diagnostic radiology and it therefore seemed justi fied to report the experiences in this department in Uppsala Since 1972 in collaboration with the Department of Orthopaedic Surgery arthrography has been carried out after the neonatal period in children with suggestion of hip joint instability and also in a small number of children with coxa plana

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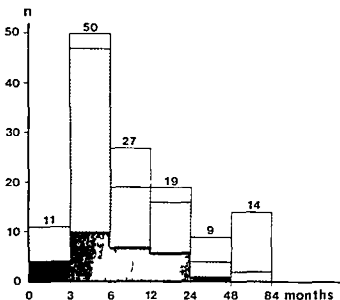


Fig 1 Age distribution and reason for referral for the initial arthrography in 130 children Black areas Congenital idiopathic instability of the hip diagnosed in the neonatal period Cross hatched areas Congenital instability diagnosed after the neonatal period Unfilled area Other reasons for referral (cf Table 1)

Table 1

The clinical diagnoses before the initial arthrography in 130 children

Diagnosis	No of cases
Congenital idiopathic hip instability	99
Coxa plana	7
Snapping hip	1
Hip joint instability associated with	
Myelomeningocele	5
Cerebral palsy syndrome	4
Other neuromuscular diseases	6
Septic arthritis of the hip	5
Arthrogryposis	
Down s syndrome	1
Total	130

A partly new technique for bilateral hip arthrography is described in the present report and the possibilities and limitations of the method for diagnosing abnormalities of the hip are discussed with special reference to the stereographic technique

Definitions

Congenital idiopathic instability of the hip joint is the term used in the following to cover all grades of congenital hip instability of unknown aetiology from slight subluxation to dislocation and is considered more adequate than the generally used term congenital dislocation of the hip

Unstable hip joint A hip joint in which the femoral head is or can be displaced from the acetabulum partially or completely

Acetabular dysplasia Abnormal ossification of the iliac bone (roof of acetabulum) observed on conventional films of the hip The chondral part of the acetabulum may appear normal or abnormal in shape at arthrography

Neonatal period The first month of life

Material

Hip arthrography was performed on 130 children (91 girls 39 boys) at this department during the period from January 1972 to December 1978 The children were examined on 185 occasions as 42 of them (34 girls 8 boys) were examined more than once Up to April 1973 only the affected hip was examined (12 children) Subsequently the initial arthrography was always bilateral (118 children) and usually also any further arthrography after the commencement of treatment (35 of 42 children) Thus a total of 351 hip arthrographies were performed

The ages of the patients at the first arthrography varied between 4 weeks and 6½ years (Fig 1) Previously conventional radiography of the hips had been performed in all children as well as clinical examinations by an orthopaedic surgeon at the hospital

The clinical diagnoses which constituted the reason for the initial arthrography are given in Table 1 In the majority of cases this diagnosis was congenital idiopathic instability Twenty consecutive cases diagnosed after the neonatal period including children with such lesion have been reported in detail elsewhere (ALMBY & LÖNNERHOLM 1978) A detailed report has also been made on 9 other children from the present series in whom treatment initiated in the neonatal period was unsuccessful (ALMBY et coll 1979)

A radiographic examination of the acetabulum was also performed post mortem in a child with normal hips who died in the neonatal period

Methods

As a rule children in whom the hip abduction was restricted by more than about 20° had been treated

by traction for varying lengths of time (up to 4 weeks) before the arthrography In a small number of cases the traction had been combined with subcutaneous adductor tenotomy

All children were examined under general anaesthesia This was carried out with a nitrous oxide/oxygen mixture (2 1) and halothane (Fluothane ICI) The patients breathed spontaneously through an ordinary mask The child was placed supine on an examination couch Before the joint was punctured a clinical examination of the hips was performed usually by an orthopaedic surgeon but otherwise by the radiologist Before arthrography an a p view of the pelvis and hips was exposed

Radiologic equipment consisted of Mimer I (Elema Schonander) connected to an image intensification system and television unit A focal spot of 0 6 mm × 0 6 mm was used

Contrast medium In the majority (335) of the arthrographies sodium meglumine diatrizoate (Urografin 290 Schering) was used The contrast medium employed in the other patients was iozomic acid (Rayodal Pharmacia) with an iodine content (209 mg/ml) specially adapted for arthrography This medium has been stated to have a long absorption time (BJORK et coll 1970) but was only manufactured for a relatively short period No detailed comparison between the contrast media was made

Puncture technique For the puncture a short bevel needle with OD 0 7 to 1 0 mm was used The needle was connected to a 30 cm long polyethylene connecting tube which was attached by a 2 way stopcock to an infusion aggregate suspended about one metre above the examination couch Before the joint was punctured the system was filled with contrast medium In children with a unilateral hip abnormality the affected hip was always punctured first The thigh was abducted about 20° and externally rotated The femoral artery was palpated just distal to the inguinal fold and the position was fixed with a finger The tip of the needle was placed on the skin surface about 1 cm medial to the arterial pulsation and the needle was then inserted in the direction of the distal part of the joint When the needle was felt to be in the correct position in the joint the 2 way stopcock was opened and a small amount of contrast medium was infused The needle was then left in situ with the connecting tube and 2 way stopcock still attached while similar equipment was attached to the infusion aggregate and the other hip joint was punctured and filled with contrast medium to the desired extent Thereafter the first punctured hip joint was immediately filled with a suitable amount of contrast medium By rotating the thighs the contrast medium was distributed in the joints In order to prevent leakage of contrast medium through the puncture track the needle (with the connecting tube and 2 way stopcock) was left in situ throughout the examination except in the first 15 arthrographies After the examination the 2 way stopcock was opened and the contrast medium was allowed to run out before the needle was removed

Only at one examination was the amount of injected contrast medium measured In this case a 5 month old girl with a normal hip joint it was 0 7 ml The degree of filling was assessed fluoroscopically at all examinations

Ninety per cent of the examinations were performed by the author and the remainder by another radiologist experienced in joint punctures in children

Exposure technique At the beginning intensifying screens of calcium tungstate were used but after 1976 rare earth screens (Lanex Regular Kodak) in combination with RP films were employed in all cases

Two techniques were tried

(1) Exposures with the use of a focused mobile metal grid (ratio 8/30) The film–focus distance was the longest possible i e 80 cm The exposure factors were 55 to 70 kV and 30 to 60 mAs

(2) Exposure without a grid the cassette with rare earth screens being placed directly under the patient whereby the film–focus distance was reduced to 75 cm The exposure factors were 55 to 70 kV and 2 to 6 mAs

A gonad shield was used in boys but not in girls In 30 children the absorbed radiation dose was measured in the rectum and on the abdominal skin by means of thermoluminescent dosemeters The rectal dose was one third to one fifth of the skin dose After 8 exposures and about 3 min of fluoroscopy in children weighing 4 to 10 kg the skin dose was 8 to 14 mGy when the grid was used for all exposures and 3 to 6 mGy when it was used for only 2 of the 8 exposures (for stereoradiography) Details about the measurements of the radiation dose in different techniques of hip arthrography will be given in a forthcoming report

Projections Well defined projections were used In the beginning of the series the two hips were ex

Table 2

The position of the legs in the six standard projections

Position No	Hips				Knees flexion	Remarks
	Abduction	Flexion	Rotation	Provocation		
1	0°	10–20°	Inward 10–20°	Pull in distal direction	10–20°	
2	0°	10–20°	Inward 10–20°	Push in proximal direction	10–20°	
3	45	0–10°	Maximally inward	–	10–20°	
4	45	10–20°	0°	–	10–20°	2 exposures at stereo examination
5	45	10–20°	Maximally outward	–	10–20°	
6	Maximum	90°	0°	–	90°	

posed separately (17% of all examinations) but later both hips were included in the same exposure The legs were placed symmetrically and fixed over the knee joints Six a p films of the pelvis with the legs in different positions were invariably exposed at the initial arthrography (Table 2)

In 80 per cent of the examinations in leg position 4 (Table 2) 2 films were exposed for stereoscopic analysis of the hip joints Between the exposures the tube was moved transversally exactly 70 mm while the central ray was directed 35 mm to the right and to the left respectively of the longitudinal midline of the patient at the 2 exposures At these examinations a plexiglass frame was placed around the pelvis and screwed into the examination table The frame was supplied with small built in metal indicators which were projected on to the films

Oblique or lateral views of the pelvis were seldom obtained A larger number of a p views of the pelvis than those mentioned were necessary in some cases

Evaluation of the films The films were evaluated immediately so that a decision could be made about treatment and as to whether this could be initiated under the same anaesthesia

The stereo film pair was inspected in a stereo roentgen comparator (StR 3 Zeiss) at a magnification of 3X The exposure of the metal indicators on the films allowed correct orientation of the images in the stereo comparator In assessing the stereo pair special attention was paid to the following The distribution of the contrast medium in the joint especially in the antero posterior direction the position of the femoral head in relation to the acetabulum especially in the antero posterior direction and the position of the head and neck of the femur i relation to the proximal femoral shaft the minera zation of the acetabulum especially of the acetab lar roof

Depending upon the findings the hip joints we classified as follows (1) Unstable hips (2) Stab hips (a) normal hips (b) hips in which the sha of the femoral head and acetabulum was abnorma (c) hips with retarded mineralization of the acetab lar roof (acetabular dysplasia) but with no oth abnormalities (3) Hips not evaluable because technical errors

The few hip joints which were assigned to grou 2b at the initial arthrography (7 hips in 7 childr with coxa plana) are not discussed in the followi For details of such cases the reader is referred t the publication of JONSATER The 31 hip join in group 2c are also excluded because most of the hips had been treated previously for congenital idi pathic instability

The normal hip joints (group 2a) included a grou which had also been found normal at all previo clinical and radiographic examinations With certa exceptions these films were used for establishi criteria for a normal arthrographic appearance of t hip The exceptions were hips in children whos contralateral hip had been treated by immobiliza tion and those in children with skeletal or neu muscular disease (e g myelomeningocele)

The criteria for a normal arthrography laid d w by FABER and SEVERIN are as follows

(1) The acetabulum must enclose slightly mor than half of the femoral head

(2) The proximal part of the edge (outer marg

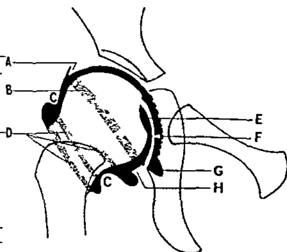


Fig Distribution of contrast medium (black areas) in a normal hip joint in infancy A p view schematic A Proximal part of the pointed and distally directed edge (outer margin) of the acetabular labrum B Layer of contrast medium dorsal to the femoral head indicating the approximate position of the dorsal part of the edge of the acetabular labrum C Orbicular zone strong circular fibres in the capsule surrounding the femoral neck preventing the joint capsule from bulging outwards D Contrast medium around the femoral neck E Fovea capitis femoris F Ligamentum capitis femoris G Contrast medium medial to the transverse ligament in the acetabular fossa H Distal part of the edge of the acetabular labrum attached to the transverse ligament causing a broad indentation The outline of the acetabular fossa is not quite smooth and the width of the layer of contrast medium between the femoral head and the fossa is greater than in the proximal part of the joint

of the acetabular labrum must be pointed like a ploughshare (SEVERIN) or a rose thorn (GRECH 1977) and directed distally (Fig 2) Further it must be located in the close vicinity of a constructed transverse line (Figs 3 4) which is tangential to the distal skeletal border of the ilium on both sides (the so-called Y line)

(3) The articular surface of the femoral head must appear spherical to the naked eye

(4) The femoral head and acetabulum must be separated by only a narrow layer of contrast medium (FABER) Slight incongruence may be apparent in some positions of the femoral head causing accumulation of contrast medium in certain places between the articular surfaces but no wide layer of contrast medium must be present between the two surfaces (SEVERIN)

The precision of the measurements of the distances presented in the following was 0 5 mm Consideration was paid to the magnification The measured distances were reduced by a factor of 0 8 at exposure technique 1 and by 0 9 at technique 2

Results

Initial arthrography Instability was demonstrated in 111 joints The normal hips included 62 which fulfilled the conditions mentioned and which could thus be used for establishing the criteria for a normal arthrographic appearance Of these hips 45 were in children 2 to 12 months old 8 were in children 13 to 24 months old and 9 were in children 25 to 72 months old

Femoral head In *normal* hip joints the size and shape of the femoral head could be easily evaluated The fovea (Fig 2) was visible on the medial aspect in leg positions 1 and 2 and appeared as a 4 to 8 mm (depending upon age) long flattened or even concave part on the otherwise evenly curved contour (Figs 3 a b 4 left hip and Fig 5 right hip) In the stereo films the position of the femoral head and neck in relation to that of the proximal femoral shaft was evaluated In no case was extreme anteversion or retroversion of the head or neck observed

In the *unstable* hips deformity of the femoral head was common ranging from slight flattening of the proximal part of the medial contour (Fig 3 right hip) to an ovoid shape An extremely small femoral head with a bizarre shape was found as a sequela to septic arthritis (Fig 5 left hip) In children with subluxation of the hip it was not always possible to determine the exact shape of the femoral head as accumulations of contrast medium between the femoral head and the acetabulum concealed parts of the dorsal outline (Fig 3 c right hip) In the stereo films definite abnormalities of the position of the femoral head and neck in relation to the proximal femoral shaft were only observed in hips with irreducible dislocation of various origins and following septic arthritis In these cases the femoral head and neck were extremely anteverted These findings were confirmed at open reduction (ALMBY et coll)

Acetabulum In the different leg positions the inclination of the pelvis varied due to the influence of the position of the lumbar spine In leg position 3 in particular the lumbar lordosis was accentuated and in position 6 lumbar kyphosis was sometimes marked This meant that different parts of the acetabular labrum were visible on the proximal and distal contours in a series of films Fig 6 illustrates how the whole edge of the labrum was projected at a post mortem examination at 4 different pelvic inclinations

In the *normal* hip joints the distance between the

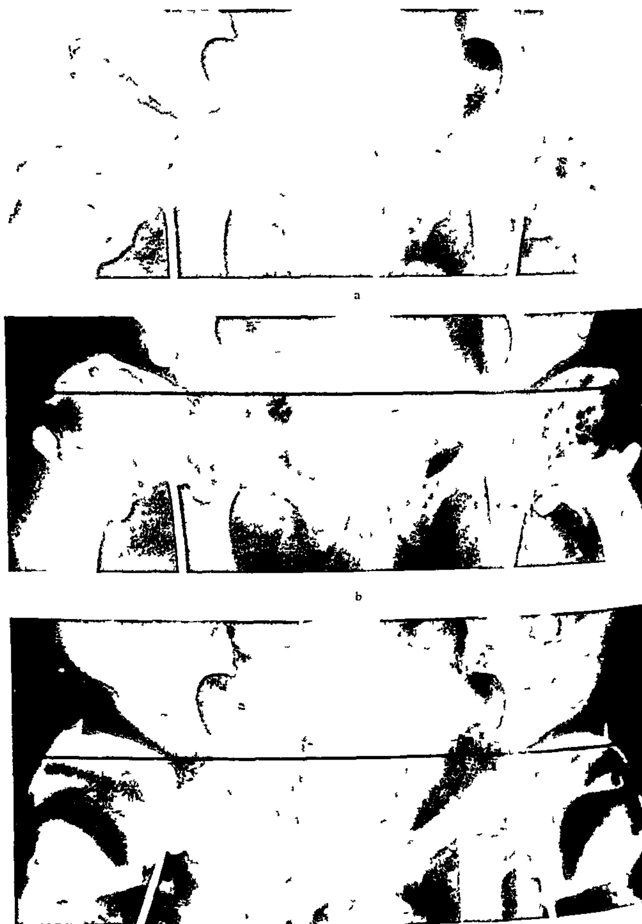


Fig 3 (For legend see opposite page)



Fig 4 Same boy as in Fig 3 9 months old after 4 months treatment in a plaster spica. Clinical examination revealed nothing abnormal The film exposed in leg position 2 On the right side the layer of contrast medium between the femoral head and the acetabulum still abnormally wide The shape of the femoral head normal Proximal part of the edge of the acetabular labrum pointed but displaced 0 5 mm proximally and directed laterally The skeletal development of the acetabular roof only slightly retarded Left hip still appears normal Fovea capitis femoris and parts of the dorsal part of the acetabular labrum are marked by the 1 to 3 mm wide oblique layer of contrast medium projected over the femoral head (cf Fig 2) Plastic tube in the rectum for dosimetry

...st proximal part of the edge of the acetabular labrum and the Y line varied by only 1 mm or less ...different films from the same patient (Fig 3 left ...p) On the other hand distinct inter individual ...fferences depending upon age were found Thus ...children aged 2 to 12 months the edge reached ...maximum of 2 mm proximal to the Y line in 21 ...f 45 hips (Fig 3 left hip) In only 6 hips did it reach ...e level of the Y line or lie distal to this line In ...ildren aged 13 to 24 months the edge was located ...tween 1 mm proximal and 3 mm distal to the Y ... Among children aged 25 to 72 months it lay ...the level of the Y line in one case and 2 to 5 mm ...tal to the Y line in the others

The edge was always pointed in shape in leg posi...ns 1 and 2 and pointed or slightly rounded in positions 3 to 6 The part of the acetabulum forming the contour was always evenly curved except at the position of the acetabular fossa (Fig 2 Fig 3 left hip) The stereographic examinations yielded the following additional information

(1) The contrast medium was largely collected in the dorsal (declivous) parts of the joints and the ventral part of the acetabular labrum was only covered in places by the contrast medium As a rule the contrast medium accumulated to form a 3 to 4 mm wide layer in the dorsal part of the joint (Fig 2 Fig 5 right hip) It was not possible to decide with certainty whether this was situated between the joint capsule and the acetabular labrum The exact position of the edge of the dorsal part of the acetabular labrum could not therefore be determined

(2) The entire articular surface of the acetabulum was not reproduced due to the distribution of the contrast medium

(3) Of the two skeletal contours that are invariably seen in the acetabular roof (on the a p view) the distal one was always located ventrally in the ilium while the proximal one was always located far dorsally They seemed to approach one another medially but their lateral parts appeared to be essentially parallel (Fig 7 right hip)

...3 3-month-old boy with right sided congenital idiopathic hip ...ty diagnosed weeks earlier a) Leg position 1 b) leg ...ion c) leg position 5 Round metal indicators projected on ...films Right hip High degree of instability The femoral head ...y deformed and can be displaced in different directions The edge of the acetabular labrum rounded in its proximal part and located 4 to 6 mm proximal to the Y line Its shape varies depending on the position of the femoral head Outline of the acetabular fossa wavy and variable The ligamentum capitis ...is partly visible in (b) Retarded skeletal development of the acetabular roof Left hip Normal



Fig 5 9 month old girl (leg position ?) At the age of 6 months instability of unknown aetiology of the left hip Cassette placed directly under the patient without grid Left side Femoral head dislocated proximal lateral and dorsal to the acetabulum It is small and has a bizarre shape indicating that the dislocation is secondary to septic arthritis Borderline between acetabular labrum and joint capsule cannot be distinguished they are interposed between femoral head and acetabulum The contrast medium has collected in the declivous (dorsal) parts of the joint preventing detailed evaluation of acetabulum Skeletal development of the ilium retarded Right hip Normal Plastic tube in the rectum for dosimetry

In *unstable* joints the appearance of the proximal edge of the acetabular labrum varied considerably In patients with subluxation the edge was clearly rounded and displaced proximally This edge of the labrum was abnormally mobile (Fig 3 right hip) In irreducibly dislocated hips the borderline between the edge and the joint capsule could not be demarcated and the two formed a fold which was interposed between the femoral head and the acetabulum (Fig 5 left hip)

At the site of the acetabular fossa the outline appeared wavy and displayed considerable variation This was due to bulging of tissue into the joint cavity (Fig 3 right hip) On optimum reduction this tissue became compressed into the acetabular fossa whereby the acetabular contour became normal In irreducibly dislocated hips on the other hand the acetabular surface could not be evaluated satisfactorily (Fig 5 left hip)

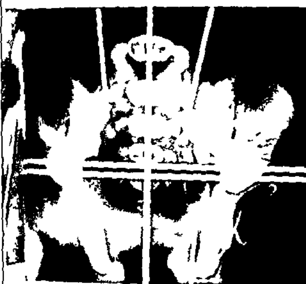
The stereographic examinations yielded the following additional information the extent of mineralization of the acetabular roof the mineralization deviated from the normal and was most marked dorsally The latter was evident from the fact that the lateral part of the two contours mentioned were not parallel the proximal (dorsal) contour diverging more or less distinctly in the proximo dorsal direction (Fig 7 left hip)

Relation between the articular surfaces In *normal* hip joints the femoral head was always situated centrally in the acetabulum in all leg positions the contrast medium accumulated in different pl... between the articular surfaces depending on t... position of the femoral head (Fig 3 left hip Fig ... right hip) When the leg was abducted 45 in... ternal rotation (position 5) the layer of cont... medium was generally widest (Fig 3c left h... It could have a maximal width of 4 mm betw... the femoral head and acetabular fossa and of ? mm between the head and the cartilaginous part of the acetabulum

In *unstable* joints the layer of contrast medi... between the articular surfaces was always wider than about 2 mm but varied in the different leg posi... tions In children with only slight instability this was most clearly observed with provocation manoeuvres (leg positions 1 and 2) or at 45 abduction and maxi... mum external rotation of the leg (Fig 3 right hi...) In patients in whom reduction was possible the opti... mum position of the femoral head was obtained in leg position 6 and occasionally in position 3

The stereo films demonstrated that the femoral head was displaced to varying extents dorsal to the acetabulum in hips with marked instability In ... er degrees of instability no such displacement was observed Only in one child who had previously had septic arthritis was the femoral head d... placed ventrally

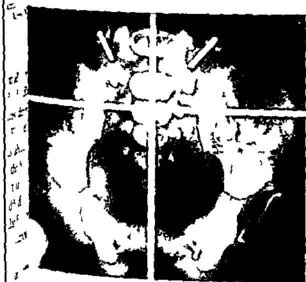
Ligamentum capitis femoris In *normal* joints th... ligament was visible in leg positions 1 to 3 ...



a



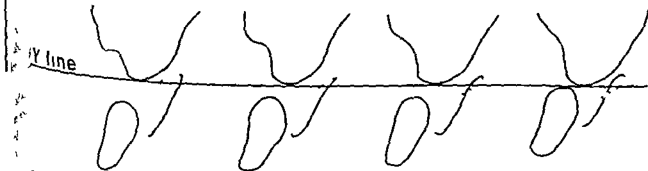
b



c



d



e

Fig. 6 Four different a p views of the pelvis obtained at post mortem examination of a child with normal hips The child was born at term and died in the neonatal period On left side the […] and joint capsule have been removed and the edge of the acetabular labrum has been marked with contrast medium […] Glaxo The central ray directed on the midline at the level of the hip joints formed an angle of 20° proximally (a) 10° proximally (b) 0° (c) and 10° distally (d) with the vertical plane Needles and metal rods used to fix the specimen projected on the films e) Left acetabulum from films a–d schematic The edge of the acetabular labrum marked with a solid line in the dorsal part and with a dotted line in the ventral part Position of the edge of the acetabular labrum in relation to a constructed line Y shown



Fig 7 Newly diagnosed congenital idiopathic instability of the left hip in an 18-month-old girl Right hip Skeletal development of the ilium normal The proximal skeletal contour (→) was observed at stereoradiography to be located dorsally and the distal contour ventrally in the ilium Left hip [illegible] dysplasia The upper part of the proximal contour (→) [illegible] from the distal contour The dysplasia thus most marked in the dorsal part of the ilium

could seldom be observed in its entire length It formed an elongated 1 to 2 mm wide defect in the contrast medium from the transverse ligament to the proximal part of the fovea capitis femoris (Fig 2 Figs 3a b 4 left hip)

In the *unstable* joints it was usually obscured by contrast medium Occasionally the ligament appeared broad (Fig 3b right hip)

The stereographic films were exposed in leg position 4 which was unfavourable for evaluating the ligament and in this respect the stereo films were of limited value

Secondary arthrography Most of these examinations were performed within one month after completion of a period in plaster of Paris Slight instability which was not perceived at simultaneous clinical examination was often demonstrated In such cases the femoral head could be displaced laterally in leg positions 2 and 5 whereupon the layer of contrast medium between the articular surfaces became wider than normally A typical case of this kind is illustrated in Fig 4 In a few patients it was also possible to displace the proximal edge of the acetabular labrum a few mm in the proximal direction A constant finding was that the femoral head had either regained its normal shape or was considerably less deformed than at the pre treatment arthrography The skeletal development of the acetabular roof had always been affected favourably (Fig 4 right hip) but had not yet become normal in more than one of 42 cases

Technical errors In 4 (1%) of the 351 punctured joints no contrast medium could be injected In [illegible] of these cases the puncture needle was prob[illegible] not lying in the joint when the injection was [illegible] tempted Both examinations were among the firs[illegible] the series and the failures could probably be [illegible] plained by inexperience In the other 2 hips [illegible] of which had been treated previously by open red[illegible] tion the contrast medium spread extraarti[illegible] even though the needle was considered to have be[illegible] situated in the joint

In the first 15 examinations it was found th[illegible] considerable amount of contrast medium could [illegible] through the puncture track when the needle [illegible] removed immediately after the injection In the [illegible] sequent examinations the needle was always le[illegible] situ until they were completed but neverth[illegible] some leakage was usually unavoidable Howe[illegible] most often it was negligible When the needle [illegible] considered to be situated in the joint but no c[illegible] trast medium flowed into it this was due to o[illegible] sion of the needle tip by a piece of tissue In [illegible] cases repuncture with a new needle was perform[illegible]

Complications No infections or local vasc[illegible] complications occurred In one patient a very tr[illegible] sient general erythema possibly caused by th[illegible] contrast medium (Urografin 220) developed a fe[illegible] hours after the examination Apart from brief [illegible] riods of bronchospasm in 2 patients probably du[illegible] to the anaesthetic agent (Fluothane) no other c[illegible] plications occurred

Exposure technique When the exposures [illegible] made with the cassette directly under the pa[illegible]

poorer quality were obtained than when the s used However the quality was considered ble (Fig 5) and at present all films except for stereoscopic analysis (which require that ient is not moved between exposures) are l with the patient lying directly on the cas

Discussion

arthrography in children is not frequently ied as the number of children with hip dis ignosed after the neonatal period in Sweden vely small During the period of the present 0 to 30 hip arthrographies were carried out r in a region with a population of about 1 2

enital idiopathic instability of the hip was the equent indication (76%) for the arthrography resent series girls were in the majority (70%) ll reported series of this condition Most report no complications at all but a few bserved isolated cases of septic arthritis ENT GRECH) The risk of side effects was re considered to be small on condition that tients without any signs of current infection xamined and that demands for sterility equal at surgery could be fulfilled Both hips were ways examined even in children with uni symptoms except in the early part of the SEVERIN also seems to have applied this le and this is also the general procedure in oint examinations in children The complica ere few and not serious

e present series it was often only after com between the affected and the unaffected hip rtain factors could be evaluated—in particular e of the femoral head the relation between noral head and the acetabulum anteversion emoral neck and the position of the proximal the edge of the acetabular labrum in relation Y line

bilateral arthrography it is recommended that ips be filled with contrast medium before ire Fewer exposures are then needed the lation time will be shorter and the hips easier npare on the films than when the two sides amined separately The exposures must be within about 10 min after the injection of the st medium If a longer time elapses the me has time to become absorbed and diluted to such an extent that the diagnosis will be rendered difficult or impossible (BJORK et coll) Using the technique described the interval between the injec tion of contrast medium on the right and left side was about one min and the exposures were com pleted about 5 min later which meant that contrast blurring was never observed The main reasons why the arthrographies could be carried out quickly and with few failures (1%) were that the technique was simple and that only two radiologists with consider able experience in joint punctures performed the examinations A new puncture technique was used and the method of injection of contrast medium employed by SAHLSTEDT (1976) for ankle arthro graphy in children was successfully applied

The joint punctures were performed at a safe distance from the femoral artery and femoral nerve —at least 1 cm medial to the arterial pulsation Re gardless of the position of the femoral head the joints were punctured slightly lateral to the trans verse ligament where the joint capsule bulges out ward to some extent (Figs 2 3c) In cases with hip instability the needle can easily be inserted far into the acetabulum (Fig 4 right hip) without contact with the articular surfaces and its tip can be moved sideways Therefore it is possible even at the punc ture stage to get an idea of whether or not the hip is unstable Several other puncture techniques have been described and are summarized by GRECH

Evaluation of the articular surfaces is rendered more difficult with much contrast medium in the joint which also increases the risk of concealment of joint structures by extraarticular leakage By leav ing the needle in the joint during the examination the amount of contrast medium can easily be ad justed to the size of the joint decreasing the risk of leakage

Lateral films of the pelvis were exposed only on few occasions and were found to be of limited diagnostic value In other descriptions of arthro graphic techniques lateral views of the pelvis are not recommended

Hip arthrography is a good example of the use fulness of stereoradiography to replace lateral ex posures At an early date SIEVERS and BRONNER mentioned the value of stereoarthrography but like FABER they did not describe the examination tech nique LAURENT always used stereoradiography in children with congenital idiopathic instability before and after attempts at reduction

At the exposures of the stereo films the geometry

was the same throughout The film–focus distance and the distance which the tube was moved laterally between the two exposures were also carefully defined The technical prerequisites for performing measurements on the films and calculating space coordinates for points in the object by means of a stereo roentgen comparator were therefore satisfied However there is a lack of reproducible measurement points in the hip joint at arthrography due to the uneven distribution of the contrast medium and this possibility could not therefore be utilized However *from the subjective assessment of the stereo* films valuable additional information was obtained In a simple way the position of the femoral head in the antero posterior direction the distribution of the contrast medium in the joint and the skeletal development of the acetabulum could be determined The stereo films revealed that severe congenital idiopathic instability in children invariably led to displacement of the femoral head dorsal to the acetabulum and that the skeletal development of the acetabular roof was most retarded in the dorsal part

Both for arthrography and for conventional radiography in children up to at least 4 to 5 years of age the use of cassettes with rare earth screens is recommended The cassette can be placed beneath the patient A metal grid need not be used

It is nowadays unusual in Sweden for congenital instability to remain undiagnosed as late as after the neonatal period and rare for the diagnosis to be made after the age of 6 months (PALMÉN 1978)

In cases diagnosed neonatally usually no radiographic examination is needed at the initial stage of treatment but routine conventional radiography at the age of a few months is generally applied (ALMBY & REHNBERG 1977) That conventional radiography has not always been a satisfactory diagnostic tool for the treatment is evident from the necessity for arthrography is some of these children (Fig 1 black areas)

After the neonatal period particularly at the ages of 1 to 6 months hip instability is often impossible to demonstrate by clinical examination alone (ALMBY & LÖNNERHOLM) Primarily conventional radiography should be used Displacement of the femur and retarded skeletal development of the acetabular roof are useful criteria for hip instability The purpose of the arthrography is to provide a guideline for the treatment and since 1972 arthrography has been used consistently in all newly detected cases

Several children with congenital instability were subjected to arthrography before the age of 6 months (Table 1) i e before they had started to bear weight on the hips Most of these cases had more or less marked subluxation (seldom dislocation) of the femoral head and a deformity of the femoral head and acetabulum (Fig 3) It is clear that even in a joint that has not borne weight deformity may occur This is probably a result of fixation of the femoral head in an abnormal position consequent upon muscular imbalance for example contractures *of the hip adductors*

Traction constituted the initial part of the treatment in children with restricted abduction (more than 20) of the hip joint By the fact that this was applied before the arthrography in most cases with reducible instability exact reduction could be achieved at the arthrography without stretching of the hip adductors and the definitive treatment (usually immobilization in a hip spica) could be initiated under the same anaesthesia Facilities were available for supplementing unsatisfactory traction therapy with subcutaneous adductor tenotomy at the radiologic department but only in a few cases was this necessary Despite these measures before the reduction femoral head necrosis in the previously unstable hip was later found in 10 per cent of a group of 20 children with congenital instability diagnosed after the neonatal period (ALMBY & LÖNNERHOLM)

Since arthrography was performed before the immobilization the treatment has been *individualized* to a greater extent than previously The duration of treatment is determined not only by the age of the child at diagnosis but also to a great extent by the degree of instability observed at arthrography Arthrography has also been found in certain respects to be a more valuable method than clinical examination for assessing the result of the primary treatment (Fig 4) In the present series some residual lengthening of the joint capsule and slight instability on provocation *manoeuvres* were often found despite the absence of abnormal findings at clinical examination That these really were cases of residual conditions and not general laxity of the joints was evident by the fact that in unilateral cases the contralateral hip joint was found to be fully stable on corresponding provocation (Fig 4)

It was also demonstrated that the cartilaginous components of the joint became favourably reshaped during the treatment This has also been

and previously in older children (SEVERIN and ...ers) However it was not certain that the femoral head had completely regained its normal shape after reduction treatment even in children under one year (ALMBY & LONNERHOLM) Therefore it would be of interest to follow up such children for a longer period than has been possible hitherto

The criteria for normal arthrographic appearance recommended by FABER and SEVERIN are based on findings at post mortem examinations (mostly new born infants) and clinical arthrographies in children over one year of age From the present series criteria for a normal arthrography in infants aged 2 to 12 months may be suggested on a more valid basis than has been possible previously

(1) The proximal part of the edge (outer margin) of the acetabular labrum *is stable even when weight is borne on the femur* The margin is pointed or slightly rounded and is directed latero distally In AP views of the pelvis the edge shall not lie at a distance of more than 2 mm on the proximal side of the Y line

(2) The acetabulum encloses a little more than half of the femoral head This is only an estimation as it cannot be expected that the entire edge of the acetabular labrum will be visible

(3) The femoral head appears spherical to the naked eye except at the site of the fovea

(4) The ligamentum capitis femoris forms a 1 to 2 mm wide defect in the contrast medium between the articular surfaces

(5) The width of the layer of contrast medium between the articular surfaces varies depending on the position of the femoral head The layer should be no wider than about 4 mm between the femoral head and the acetabular fossa and 2 mm between the remaining parts of the head and acetabulum to be regarded as normal

Conclusions

(1) Hip arthrography can be performed in infants and children with a high degree of success and a very low risk of complications

(2) It is of advantage to perform the examination under general anaesthesia at least in children under about 7 years of age

(3) Arthrography yields detailed information about the size shape and position of the femoral head and of the configuration of the joint cavity Information though not detailed is also obtained on the anatomy of the acetabulum and the ligamentum capitis femoris Stereoradiography will give further information on the hip joint

(4) An orthopaedic surgeon should be present at the arthrography His task should be to perform a clinical examination of the hips *before the joint is* punctured and to be prepared to initiate the most suitable form of treatment e g immobilization with a hip spica after closed reduction under the same anaesthesia

SUMMARY

A method by which bilateral hip arthrography was performed under general anaesthesia in 130 infants and children 1 month to 7 years of age is described Significant contractures of the adductor muscles had been corrected before the examination Most of the children were girls with unilateral congenital idiopathic hip instability detected before the age of one year From films exposed in standardized projections valuable information was obtained about the configuration of the joint cavity and the size and shape of the femoral head Criteria for normal appearance in infants of ages 2 to 12 months are presented More reliable details on the relation between the articular surfaces the radiographic anatomy of the acetabulum and the distribution of the contrast medium were yielded by stereoradiography Closed reduction was usually accomplished successfully during the arthrography which *made beginning of definitive treatment under the same* anaesthesia possible

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ROM THE ORTHOPEDIC CLINIC AND THE SECTION OF PEDIATRIC RADIOLOGY DEPARTMENT OF DIAGNOS TIC RADIOLOGY MALMO ALLMANNA SJUKHUS S 21401 MALMO SWEDEN

AVULSION FRACTURE OF THE PROXIMAL TIBIAL METAPHYSIS

Report of a case

L DANIELSSON and G THEANDER

ımatic injury to the knee in childhood may e various types of fractures involving the al metaphysis of the tibia Most of these are common and well known but avulsion of a hyseal fragment has apparently not been de d previously The present report concerns the gic diagnosis of such avulsion and an analysis factors responsible for this exceptional type of e

Case report

-year-old girl was vaulting the buck horse during stic classes at school Missing a jump she hit the r surface of her left knee against the top of the The injury was first believed to be trivial but after s she sought medical advice because of increasing d difficulty in walking

cal examination revealed that when walking the ed her pelvis backwards and that her steps were short The left knee was slightly swollen but the ng skin was normal in colour although its tempera peared somewhat elevated Pain and distinctive ess were located not to the actual site of the blow the dorsal aspect of the medial tibial condyle The rovoked a 20° extension deficit of the joint This ion of movement as well as the pain were exagger flexion of the hip ESR was 38 mm in one hour raphs of the left knee was reported to show os and sclerotic abnormalities of the tibial meta and a periosteal reaction

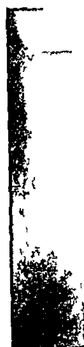
findings were considered suggestive of os elitis or tumour and biopsy was scheduled at a for the diagnosis and treatment of bone tumours ms were sent in advance but were lost Therefore radiography was repeated 15 days after the accident The tibial metaphysis was again found to be irregular in struc ture but the previous diagnosis proved to be incorrect the trabecular disarrangement was caused by a fracture with incipient callus This fracture which was confirmed by tomography extended from the epiphyseal plate 4 cm distally separating a posteromedial fragment of the metaphysis The fragment was wedge shaped tapering distally and consisted of trabecular as well as cortical bone Slight tilting of the fragment had resulted in a dias tasis which also tapered distally (Figure)

Close inquiry into the history revealed the following circumstances of the accident When approaching the vault ing horse the girl noticed that the springboard deviated to the left During takeoff the board slipped and the jump got askew The girl tried to adjust the vault by maximum abduction of her left leg but could not avoid hitting the horse with the left knee which was extended whereas the hip was abducted and rotated outwards The collision forcefully flexed the hip and simultaneously pain was experienced not only at the site of the blow which was anterior but also on the posteromedial aspect of the knee

After the fracture had been recognized the request biop- sy was cancelled and the knee was immobilized in plaster which was removed 10 days later By then the knee was no longer painful and joint motion had become normal but the circumference of the left thigh had decreased by 2 cm Periarticular demineralization had occurred but the radiographic findings were otherwise unaltered No fur ther treatment was given After another month healing of the fracture was complete the muscular atrophy and the demineralization had disappeared and also the ESR was normal Nine months after the accident she had resumed physical training and was in an excellent condition

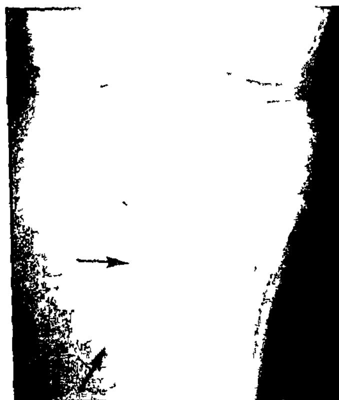
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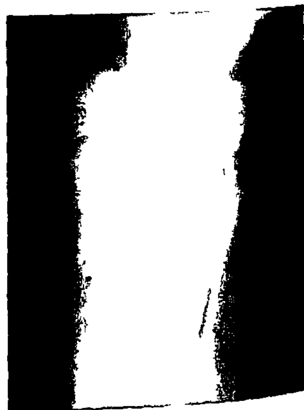



a

b



c



d

Left knee 1? days after accident a) A p view b) tomography c) oblique view Fracture (→) d) Lateral view tomography Posteromedial *fragment of metaphysi* slightly di placed

Discussion

It is evident that the fracture sustained in the present case was not directly c used by the impact of the knee against the horse The dorsal position of the

fragment and the diastasis clearly indicate avulsi fracture This is a common type of sport injury i childhood and adolescence but the usual sites of avulsion are the epiphyses and various apophys ossific ition centers A truly metaphyseal avul

o have never before been observed in any he site of metaphyseal avulsion in this case consideration of some special anatomic of the knee joint

eas the posterior and medial surfaces of the l tibial epiphysis are covered by the synovial ine which extends to the cartilaginous eal plate the adjacent part of the metaphysis of attachment of the fibrous joint capsule & WACHSMUTH 1972) The medial wall of the is interwoven with the broad medial collate nent and its posterior wall is similarly sup mainly by the semimembranosus tendon Be e knee joint this flat tendon divides into 3 bundles of fibres which partly blend with the The middle bundle extends distally into the l fascia as well as to the tibial metaphysis lar bundle turning proximally forms the ob opliteal ligament of the capsule and the tibial which runs a more transverse course in the tibia beneath the medial collateral liga OPSCH 1940)

tendons of the semimembranosus and dinosus muscles form the medial ham whereas the lateral hamstring consists of the tendon The semitendinosus tendon inserts tibia but this attachment close to the tibial sity is mediated by the pes anserinus which is composed by other tendons The biceps ten attached mainly to the fibula Since the long f the biceps muscle and both of the medial ing muscles originate at the ischial tuberosi of these muscles are extensors and adductors hip as well as flexors of the knee The embranosus and simitendinosus muscles also inward rotators of the leg (APPLETON et coll

n the knee is extended the tension of the ring muscles will restrict flexion of the hip If tended knee is abducted forceful flexion of may cause an avulsion fracture at the ischial sity where all of the strong hamstring mus riginate Such avulsion may occur on the side leading leg of a hurdler and is frequently found fter other strenuous activities such as acro- dancing football sprinting and skiing (MILCH SCHLONSKY & OLIX 1972 LEHNHARDT & SCHI 1974 EKLÖF et coll 1979) However if g is in a similar position but also rotated out the biceps muscle will be relatively lax and articipate in the traction acting on the ischial tuberosity Under these special conditions the tension of the medial group of hamstring muscles might avulse their tibial rather than their ischial attachment

Vaulting the horse requires a combination of abduction and outward rotation of the hips and extension of the knees but since the rules stipulate vertical posture of the body when passing the horse the hips at this moment should not normally be in a position of flexion But if the legs hit the horse their sudden arrest will tilt the body forward The resultant flexion of the hips might be expected to cause an avulsion fracture either at the ischial tuberosity or less likely at the tibial insertion of the hamstring tendons yet even the ischial site of avulsion seems to be rare in this sport Since collision with the horse can obviously not be uncommon the tibial fracture observed in the present case strongly suggests some extraordinary kind of strain on the medial hamstring of the left leg

It is therefore noteworthy that the accident was claimed to have been caused by skewness and slipping of the springboard and that the manoeuvre made to overcome these difficulties implied exaggerated abduction of the left leg When hitting the horse the leg was thus in an unusual position which is known to favour avulsion and which also explains the remarkable site of fracture

The initial erroneous evaluation of the injury may have been due partly to the abnormal ESR which seems to have been merely coincidental but the extreme rarity of metaphyseal avulsion is probably the main explanation why recognition of the fracture was delayed Awareness of the fact that this type of avulsion can occur and knowledge of its radiologic appearance should help to prevent future confusion with other lesions

SUMMARY

The radiologic appearance of avulsion fracture of the proximal tibial metaphysis is described and the conditions under which this rare type of injury may occur are analysed

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FROM THE SECTION FOR PEDIATRIC RADIOLOGY UNIVERSITY HOSPITAL S 185 LUND SWEDEN

EFFECTS OF PERCUTANEOUS FEMORAL ARTERY CATHETERIZATION ON LEG GROWTH IN INFANTS AND CHILDREN

W MORTENSSON

Several reports have pointed out the risk that catheterization of the femoral artery causes retardation of leg growth This complication has been mentioned in casuistics the observed differences in length between the two legs ranged between 5 and 35 mm (RUDOLPH 1968 WHITE et coll 1968 NEBESAR et coll 1969 TAKAHASHI & KAWANAMI 1970 JACOBSSON et coll 1973 BLOOM et coll 1974)

The phenomenon has also been systematically investigated BASSETT et coll (1968) found shortening of the leg on the catheterized side in 24 of 28 children aged 0 to 14 years who had been subjected to femoral artery catheterization after surgical exposure The difference in length between the legs varied from 3 to 18 mm the tibia being primarily affected

The risk of growth retardation after percutaneous catheterization has also been investigated ROSENTHAL et coll (1972) found the distance from the anterior superior iliac spine to the lateral malleolus of the ankle joint to be at least 8 mm shorter on the catheterized side than on the other leg in almost 3 per cent of the children The authors also commented upon the inexactness of the external measuring technique HAWKER et coll (1973) probably using external measurement found that the length of the legs agreed within ±5 per cent the findings were not further commented upon but seem to include children with a considerable leg length inequality GAUTHIER et coll (1973) were unable to prove any risk of inducing growth retardation by percutaneous catheterization However they found that usually the two legs varied in length With the exception of one third of the patients of GAUTHIER et coll assessment of the leg length was not made before catheterization

BASSETT et coll found that the degree of growth retardation in the catheterized leg paralleled the decrease in ipsilateral peripheral arterial pulses as estimated by oscillometry or by palpation They therefore considered thrombotic complications to be the cause of impaired growth Thrombosis of the femoral artery was in fact demonstrated by angiography in a few cases (WHITE et coll JACOBSSON et coll BLOOM et coll) in most instances following catheterization after surgical exposure of the artery

Further experiences are necessary to elucidate the relationship between growth disturbance and percutaneous catheterization of the femoral artery prevention and treatment of the complication depends on knowledge of its causes and the natural history and clinical significance of the subsequent inequality in leg length

Material and Methods

The material comprised 78 infants and children in whom percutaneous catheterization via the femoral artery had been performed Approximately 80 per cent of the patients had been subjected to heart catheterization and the remainder to catheterization of the coeliac superior mesenteric or renal arteries

The material was divided into two main groups Group I consisted of 42 patients who had undergone previous heart catheterization by means of catheter insertion through one of the femoral arteries and were submitted for another similar examination All children admitted during a given period and fulfilling these criteria were included irrespective of whether or not possible thromboembolic complica

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Table 1

Age (years) at catheterization and length (years) of follow up in 78 infants and children exposed to percutaneous catheterization of the femoral artery

	No of cases	Age at catheterization				Length of follow up		
		Range	Median	Mean	SD	Median	Mean	SD
Group 1 A	9	0–9	2 1	2 8	3 4	6 3	5 5	2 7
Group 1 B	4	0–12	4 5	4 2	5 0	3 0	3 1	1 9
Group 1 C	6	0–9	2 4	3 2	3 3	4 2	4 4	2 9
Group 1 D	23	0–14	6 0	6 3	4 2	3 0	3 3	1 5
Group 2	36	0–14	6 4	7 1	3 7	1 5	2 0	1 3

tion existed in fact such a complication was suggested in one case only In conjunction with repeat cardioangiography angiography of the iliac arteries and the previously catheterized femoral artery was also performed (MORTENSSON 1976) The length of the legs was measured at the same time The angiographic findings guided the further classification of the patients into 4 subgroups 1 A with total occlusion and 1 B with partial occlusion of the previously catheterized femoral artery 1 C with minor thrombotic lesions in the artery and 1 D with a normal artery

Group 2 consisted of 36 patients The lengths of their legs were assessed immediately before the primary catheterization and again at the follow up Since there was no clinical suggestion of thrombotic complication angiography was not performed

The age of the patients at catheterization and the length of the follow up period i e the time lapse between the catheterization and the follow up are given in Table 1 This period was in no case shorter than one year

The pre-catheterization measurements of the legs of 122 infants and children including the patients in group 2 were used as reference values

The length of the femur and the tibia was recorded separately by means of orthodiaradiography With the leg resting directly on a long cassette 3 exposures were made in sequence on the same film using FFD 150 cm and slit collimator with the central beam focused precisely on the hip knee and ankle joint respectively (Fig 1) The leg and the film were kept stationary during the procedure The length of the bones was then measured directly on the film Two complete sets of films and measurements were made of each bone the average being used

The reliability of the measurements was analyzed by the variance of the results from the two measurements of the same bone and expressed by standard deviation Whether the length of the femur or the tibia was assessed the standard deviation was approximately 0 5 mm and was nearly the same at all ages Any difference in length between the two legs of less than 2 mm may thus be explained by the measuring error

The absorbed dose was 0 2 mJ weighted mean active bone marrow dose 30 μGy and gonadal dose 30 μGy to a 6 year-old boy (the median age in the material)

Results

The reference group The difference in length between right and left femur right and left tibia and right and left leg (=femur plus tibia) respectively appears in Table 2

Difference in length between mate bones occurred with equal frequency in all ages and was of practically the same magnitude In 60 per cent of the cases the length difference between the two legs was within 1 mm in 2 cases it was more than 10 mm (Fig 2 c) No predominance in bone length on either side was found

Table 2

Difference (mm) in length between the femora and the tibiae and also between the femur plus tibia (total leg) of the 2 sides in 122 infants and children constituting a reference group

	Range	Mean	SD	SEM
Femur	0–11	1 5	1 5	0 13
Tibia	0–7	1 5	1 6	0 14
Total leg	0–7	1 5	1.5	0 14







Fig 1 At orthodiaradiography 3 different exposures were made on the same film with the central beam focused on the hip- knee and ankle joint respectively The length of femur and tibia was measured separately on the film

Group 1 The results of the length measurements – given in Fig 2 and Table 3 Leg length inequality was not encountered among the patients with un complicated catheterization (subgroup 1 D)

Patients with thrombosis following catheterization of the femoral artery frequently had shortening of the ipsilateral leg The degree of growth retardation roughly paralleled the severity of the thrombotic lesion The femora were primarily affected and in the subgroups with total or partial occlusion of the femoral artery (subgroups 1 A and 1 B) the length inequality between the catheterized and non-cathe terized side was statistically significant ($p<0.001$)

The tibia was also shorter on the catheterized side in several cases however the mean value of length discrepancy did not differ significantly from that of the reference group

Group 2 The difference in growth between the bones on the catheterized and the non catheterized side during the follow up period appears in Fig 3 No general difference in the growth rate of the bones on the two sides existed In one child a slight de crease was found in growth rate of the leg on the catheterized side as compared with that of the other leg and in 7 instances the growth of the catheterized leg exceeded that of the other leg

Discussion

A good conformity in length existed between the right and left leg in most of the individuals of the reference group A discrepancy in length of less than 5 mm must be accepted as normal (Table 2) Even a greater length difference may occur without caus ing complaints (SHARRARD 1971) Eight mm was therefore somewhat arbitrarily chosen as the small est limb inequality which possibly may cause symp toms this would give a margin of confidence and make comparison possible with previous reports on growth retardation following arterial catheterization

Leg inequality of 8 mm or more occurred in 5 of the 78 catheterized patients All 5 belonged to group 1 and thus there was no information on a possible length discrepancy present already before the pri mary arterial catheterization In 3 cases the catheter ized leg was the shorter one and the differences in length were therefore intuitively classified as result ing from complications This would then give ap proximatively the same frequency of growth retarda tion as found by ROSENTHAL et coll In two of the cases with marked length inequality the shorter leg was on the non-catheterized side and angiography showed normal arteries This emphasized as did the 2 cases in the reference group with marked differ ences in leg length the risk of erroneously ascribing a shorter leg on the catheterized side to catheteriza tion complication Nevertheless the close relation between thrombosis in the catheterized femoral artery and growth retardation of the ipsilateral leg and the reverse situation i e no growth retardation when the artery was normal strongly supported the hypothesis that arterial thrombosis was the cause of growth retardation The probability that the results demonstrated in Fig 2c would occur at a random

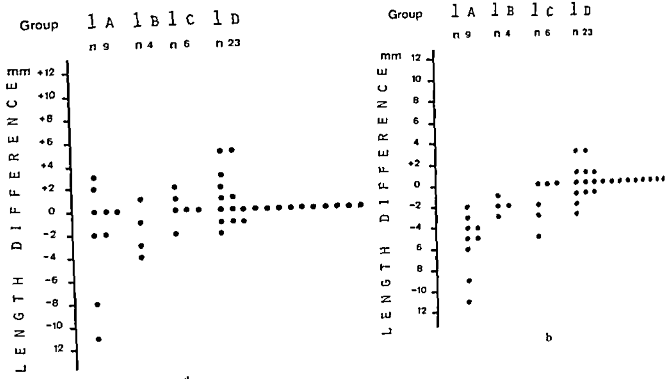


Fig _ Difference in bone length between catheterized and non catheterized sides in 4 children expo ed to percutaneous femoral catheterization Each dot represents one patient Postive difference indicates that the catheterized bone is longer Patients arranged in groups according to occurrence and degree of thrombotic lesions in catheterized artery a) Tibia b) Femur c) Total leg

distribution w is less than 0 01 Premature closure of the physis did not occur in any case

The ultimate degree of leg shortening in patients with thrombosis varied and was possibly related to the age of the patients at the time of catheterization —the younger the patients the greater the growth retardation The phenomenon could not be furt evaluated however because of the small number patients with confirmed thrombotic complicat and because most of them belonged to the same group Any growth retardation factor will caus greater leg length inequality if it occurs durin

Table 3

Group I. Length difference (mm) between femur, tibia and femur plus tibia (total leg) of the catheterized and non-catheterized side in 42 children previously exposed to percutaneous catheterization of the femoral artery. The patients are arranged according to the condition of the previously catheterized artery as assessed at angiography

Group 1	No of cases	Length difference					
		Femur		Tibia		Total leg	
		Mean	SD	Mean	SD	Mean	SD
A Total occlusion	9	−5 6	?7	− 0	1 6	− 9	
B Partial occlusion	4	−?0	0 8	−1 8	_5	− 8	0
C Discrete thrombosis	6	−1 7	1	+0_	1 3	−1	3 0
D Normal artery	23	+0 1	1 4	+0 5	1 8	+0	

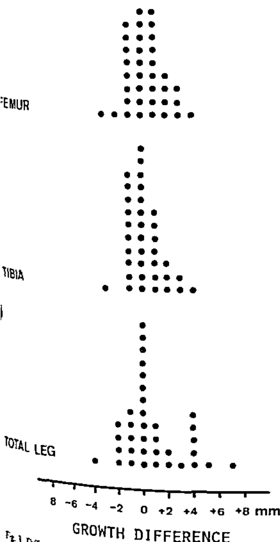


Fig. 3 Difference in growth of bones between catheterized and non-catheterized sides during follow-up period in 36 children exposed to percutaneous femoral catheterization. Positive value indicates that growth was greater on catheterized than on non-catheterized side

period of otherwise rapid growth as in infancy and early childhood (ANDERSSON et coll 1964)

The duration of the growth impeding action is also related to the ultimate length inequality of the legs However no relation could be proved between the degree of leg length difference and the length of the follow up period The longer follow up period present in children with thrombosis following catheterization is ascribed to the fact that most of the thrombotic complications occurred during the early period of the series In this context it should be mentioned that preliminary results of an investigation in progress suggest that the growth retardation effect following thrombosis of the femoral artery seems to operate a definite limited period only The growth rate of the mate bones is then re equalized

If the difference in length between the two legs amounts to 10 mm the leg inequality may give rise to low back pain and gonarthrosis in adults (DIXON & CAMPBELL SMITH 1969 CLARKE 1972 WALSH 1973) Therefore it may seem advisable to take corrective measures to prevent such complaints However according to SHARRARD leg length discrepancy in children will rarely be considered for correction unless it is at least 25 mm In the present series leg length discrepancy of at least 10 mm was observed after catheterization in 2 children a frequency identical to that of the reference group The length differences were 11 and 20 mm respectively and the only symptoms were limping and the need of operative correction was thus questionable according to SHARRARD s criteria The risk of causing clinical significant leg length inequality at arterial catheterization is therefore considered to be

More marked differences in leg length have been reported and it is apparently not completely clear what troubles even moderate leg inequality may cause later on in life (CLARKE) Measuring the leg length after catheterization seems therefore to be advisable Careful exterior measurements should be sufficient as a screening test

The present results strongly suggest that thrombosis of the femoral artery was the sole cause of growth retardation The primary step in preventing growth disturbance is therefore to make an adequate assessment of the blood flow to the catheterized leg after completed catheterization and if thrombosis has occurred to perform thrombectomy without delay If growth disturbance has been established the ultimate degree of length difference can probably be determined after 18 to 24 months

SUMMARY

The risk and the mechanism of inducing leg growth retardation at catheterization of femoral artery was investigated in infants and children The ultimate degree of leg inequality and the possible clinical significance of the complication were discussed

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FROM THE SECTION OF PEDIATRIC RADIOLOGY DEPARTMENT OF DIAGNOSTIC RADIOLOGY AND THE ORTHOPEDIC CLINIC MALMÖ ALLMANNA SJUKHUS S 21401 MALMÖ SWEDEN

VOLUNTARY HABITUAL DISLOCATION OF THE HIP IN CHILDREN

H PETTERSSON G THEANDER and L DANIELSSON

Recurrent dislocation of the hip may be a sequela of traumatic injury (GLASS & POWELL 1961 HENSLEY & SCHOFIELD 1969 DALL et coll 1970 GAUL 1973) It may also be due to skeletal dysplasia or to joint laxity caused by malformation or by disease of the connective tissue (HASS & HASS 1958 PACKER et coll 1972 HADDAD & DREZ 1974) Voluntary habitual dislocation of the hip in childhood is a condition in which none of these explanations seems to be valid The present report concerns the clinical and radiologic features of this unusual disorder

Case report

The patient is a boy with no family history of musculoskeletal disease He was born at term of a normal pregnancy and routine examination in the maternal ward including palpation of the hip joints revealed nothing abnormal He learned to walk at 12 months of age At 2½ years he was admitted because of nocturnal leg pain His mother could give the child relief by massaging his legs and during such massage she had heard clicking of his hips Clinical examination still revealed nothing abnormal and no treatment was given

One year later the boy had developed the habit of producing a loud click by combined flexion adduction and [illegible] rotation of the left thigh He had no pain and he enjoyed practising the habit in bed which disturbed his parents sleep Clinical re examination revealed slight hyperextensibility of the first metacarpophalangeal joints but the movements of the hips appeared normal Radiography of the pelvis in the supine position at rest revealed nothing abnormal (Fig 1) On request the boy proved capable of dislocating the left femoral head posteriorly Cineradiography demonstrated that the dislocation was very brief the maximum dislocation lasting less than 0 2 second At the mom[illegible] click wa[illegible] heard and gas appear[illegible]

No treatment was [illegible] parent [illegible] to persuade the boy to [illegible] habit [illegible] the boy had not produced any click for more than a year and had almost forgotten how to do it The clinical and radiologic findings were normal However after instruction the boy was able to repeat his old trick and cineradiography again confirmed brief posterior dislocation of the left femoral head though less marked than previously Intraarticular gas occurred instantaneously on the dislocation as before but no clicking was heard

Survey of previous cases A search of the literature revealed 6 previous cases in which voluntary recurrent dislocation of one or both hips has been radiologically demonstrated in childhood (HILGENREINER 1932 HEIDSIECK 1939 HEIKKINEN & SULAMAA 1971 BROUDY & SCOTT 1975) The main findings in these cases are briefly summarized in the Table which also gives the sex of the children the age at which symptoms of the dislocation had first been noticed and the age at confirmation It appears that 5 of these 6 children were girls with dislocation of the right hip whereas the boy had bilateral dislocation that the diagnosis was established at 2 years of age in one case and at about 5 years in the others that the dislocation was invariably accompanied by a clicking sound and by the occurrence of intraarticular gas and that it was painful in only one case

The clicking sound was invariably heard on dislocation and in one case also on reduction (Case 1)

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Fig 1a



Fig 1b



Fig 1 Normal a p view of the hips at 3½ years

Fig 2 Cineradiography at flexion adduction and inward rotation of left thigh Intraarticular gas in posteriorly dislocated left hip

Fig 2

Intraarticular gas was stated to occur on the dislocation in Cases 2 and 6 and can also be observed in the illustrations in Case 1 Although in the last mentioned case HILGENREINER seems not to have realized that gas was present in the joint he observed that when the femoral head was displaced the ligamentum teres became radiologically visible

The dislocation was described as posterior in 5 cases and seems to have been so also in the remaining one (Case 1) In all the cases it was provoked by flexion adduction and inward rotation of the thigh No laxity of other joints was found except in Case 4 in which the fingers wrists and knees were hyper flexible and hyperextensible and in Case 6 in which the shoulder joints later proved unstable

Case 4 is exceptional also in other respects The mother of this girl had had recurrent dislocation of both shoulders and one of her knees After the ne[illegible] hip of the daughter had begun to click it occasionally became locked in the faulty position and had to be reduced by traction The hip was sometimes painful and she began to limp Despite this history the hip proved only slightly unstable when first examined at 3 years of age and radiography as well as arthrography at that time revealed no abnormality except slight widening of the joint space Two years la[illegible]

Table

Previous reports of habitual voluntary dislocation of the hip in childhood

Reference	Sex	Age (years) at onset of symptoms	Age (years) at confirmation	Side	Pain	Clicking		Intra-articular gas	Treatment
						On dislocation	On reduction		
HILGENREINER	F	2	2	R	–	+	–		[illegible]
HEDGECK	F	<4	5	R	–	+	–		[illegible]
HEIKKINEN & SULAMAA	M	1½	5	R L	–	+	–		[illegible]
HEIKKINEN & SULAMAA	F	<2	5	R	+	+			[illegible]
BROUDY & SCOTT	F	4½	4½	R	–	+	–		
BROUDY & SCOTT	F	Unknown	5	R	–	+			

the dislocation was radiologically confirmed the symptoms had progressed and the muscles of the right thigh had become atrophic The hip was therefore treated surgically and immobilized for 3 months postoperatively At operation the joint capsule was found to be wide enough to permit intracapsular dislocation of the femoral head but was otherwise normal. The ligamentum teres was missing but the acetabulum labrum glenoidale and femoral head were normal After overlapping and plication of the capsule posteriorly the dislocation could no longer be provoked on the operation table At repeat examination one year later dislocation had allegedly not recurred The hip movements and the radiologic findings were then normal

One child was treated with immobilization of the hip for 9 months (Case 2) She was then symptom free for a year after which habitual dislocation recurred In another case immobilization with an abduction splint was tried (Case 3) but dislocation occurred even in the splint which was therefore discarded This child still had habitual dislocation at 8 years of age but when re-examined at 16 years the hips had become stable and were clinically and radiologically normal

Follow up was included also in the reports of 2 children who received no treatment One of these was still a year later able to dislocate the hip but had abandoned the habit (Case 5) The other one was re-examined after 7 years (Case 6) She no longer dislocated the hip which appeared clinically and radiologically normal but in the meantime she had developed the ability to provoke posterior subluxation of both shoulder joints

Discussion

The present case of voluntary habitual dislocation of the hip and the previous 6 cases shown in the table display several strikingly similar features viz the history prompting examination the early onset of symptoms the posterior dislocation of the femoral head the manoeuvre provoking the dislocation and the clinical and radiologic findings The children had neither a history of trauma nor any congenital or acquired dysplasia and nothing indicated a previous disease One girl had pain in the affected hip atrophy of the thigh and a limping gait (Case 4) but since these slight disabilities gradually developed after dislocation had become habitual they were probably exceptional complications of the habit rather than manifestations of any predisposing abnormality Pain is not known to have occurred in the other cases except the present one in which it was only transient

Further features common to most of the children include female sex (5 cases) unilateral affection (6 cases) right sidedness of dislocation (6 cases) and stability of all joints other than the hips (all cases except one in which the ability to subluxate the humeral heads later developed) Hypermobility of some joints e g in the hands was noticed in 2 cases but since this finding is not uncommon in childhood its significance is doubtful The follow up available in 6 cases shows no tendency of the dislocation to become permanent or to cause severe injury Although limited experience suggests that the habit of dislocation may be abandoned even without treatment

Since most of the features mentioned differ from those of other dislocations of the hip it appears justified to conclude that the unusual ability to dislocate the hip voluntarily constitutes a specific pediatric entity It seems to involve preferentially the right hip of otherwise normal young girls for a limited period of time In the diagnosis of this entity the typical history is of obvious importance but also the findings at clinical and radiologic examination appear significant The occurrence of a clicking sound and of intraarticular gas deserves particular interest

Although the sound in Case 1 was claimed to occur both on dislocation and on reduction in all other cases it was heard only on dislocation It thus differs from the slight clicking sometimes found in newborn infants with congenital dislocation of the hip On palpation the neonatal clicking is elicited at the moment when the femoral head is felt to slip back to a normal position (the so called Ortolani click) The sound heard on voluntary habitual dislocation appears to have invariably been rather loud resembling that produced in many normal subjects when traction is suddenly applied to a joint e g in a digit

As early as in 1897 it was radiologically demonstrated that the sound elicited in a finger joint by traction is due to momentary loss of contact between the joint surfaces and that at the same moment gas occurs in the joint space (FICK 1910) Since then gas has been found under various circumstances in many other joints including the hips (for references see MAGNUSSON 1937 RAVELLI 1955) Such an accumulation of gas has often been referred to as a vacuum phenomenon because it is explained by reduction of the intraarticular pressure liberating gas from the tissues THOMAS & WILLIAMS (1945) who examined the knees of healthy subjects in a decompression chamber showed that gas invariably appeared in these joints on simulated rapid ascent to 35 000 feet (about 10 670 m) altitude They aspirated the gas for analysis and found it to consist of nitrogen oxygen and carbon dioxide in approximate equilibrium with the normal blood gases

Even at ordinary altitudes gas may occur without traction in some joints particularly when the limbs are held in certain positions This was first noticed in the shoulder by MAGNUSSON who found that gas sometimes occurred in the joint if in the recumbent position the arm was extended along the head and that it disappeared on flexion In the hip gas may be seen in a lateral view obtained in the recumbent position (the so called frog or Cleaves position o the hip also called Lauenstein s position) but r d s appears at change of posture (SEYSS 1959) The events which quite frequently may be observed children with normal joints suggest that in the h and shoulder the intracapsular space varies in vo ume with the position of the limbs

It might be thought that gas would a cum la even more readily in a joint when dislocation occu but in most dislocations this seems to be preve by abnormalities not allowing sufficient reduction the intraarticular pressure In dislocation caused malformation or trauma the capsule may be inco plete or have been ruptured and in neurogenic a various other types of dislocation the normal su port of the surrounding tissues is absent It is know from post mortem experiments with human jo that if the soft tissues outside the intact capsule ha been removed traction separating the joint surfa will cause the capsule to bulge into the joint spa which is thereby reduced or even eliminated (FICK HEIDSIECK found at radiography of a case w habitual dislocation of the hip caused by progressi muscular dystrophy no gas to occur in the jo when the femoral head was being dislocated assumed that in this disease a similar absen e capsular support in vivo prevents gas from a cumulating in the joint

Radiologic observations made at the mom when dislocation occurs or immediately afterwa have been rare except in infants with con n dislocation of the hip In this hospital the disloca in such infants is radiologically demonstrated in first week of life The examination is made af dislocation has been detected on palpation a films are exposed while the femoral head is manua displaced The films invariably include a p views both hips obtained in the frog position with a without traction of the thighs In a recent report the radiologic findings the films in 124 newborn fants with dislocation of one or both hips were viewed (PETTERSSON & THEANDER 1979) Desp the traction gas was never observed in the hip jo whether dislocated or not

In congenital dislocation of the hip a trans abnormal laxity of the soft tissues of the pelvi a hips is a precondition for the displacement of femoral head (ANDRÉN 1962) The observed fa of dislocation and traction to provoke a cumula of gas in the hip joints in newborn infants wi h t disease is therefore not surprising but the obser

en is noteworthy in the present context because it tor ly suggests that neither dislocation nor traction will cause gas to accumulate in a joint unless the capsule is effectively supported by surrounding tissues

It might consequently be assumed that in habitual voluntary dislocation of the hip the gas invariably found to occur in the joint reflects not only completeness of the capsule but also proper stability of its surroundings The findings made at operation in case 4 and the course of the condition in the cases followed up are consistent with this assumption The demonstration of gas in the joint thus appears to be valuable both as a clue in the differential diagnosis between the various kinds of habitual dislocation and as an indication of a favourable prognosis

SUMMARY

The clinical and radiologic findings in a child with habitual voluntary dislocation of the hip are reported Observations made in this case and in 6 others on record suggest that this rare condition is a specific pediatric entity with a good prognosis

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FROM THE SECTION OF PEDIATRIC RADIOLOGY DEPARTMENT OF DIAGNOSTIC RADIOLOGY AND THE PEDIATRIC CLINIC MALMO ALLMANNA SJUKHUS S 21401 MALMO SWEDEN

CONGENITAL DEFORMITIES OF SKULL CAUSED BY FETAL LIMBS

G THEANDER and J THUNANDER

Moulding of the head of the fetus is a physiologic event during delivery but this change in shape is sometimes abnormal in degree site or duration and moulding may occur also before birth Skewness of the face for example with malocclusion of the bite may develop in utero if the fetus habitually keeps its head turned to one side the lower jaw being pressed against the shoulder This origin of facial moulding was detected by PARMALEE (1931) and independently by BROWNE (1936)

Prenatal moulding of a calvarial bone has occasionally been shown to result from maternal abnormalities such as a uterine fibroid (BARR 1952) but may be caused also by the fetal limbs When examining a newborn baby with congenital bilateral impression of the forehead and slight malformation of the feet BROWNE noticed that on extension of the legs and flexion in the hip joints each foot thus brought into contact with the forehead fitted into the ipsilateral concavity of the skull He concluded that both types of deformities had been provoked by mutual pressure exerted by this position of the legs

In the 2 cases now reported congenital deformities of the skull are explained by the position of the fetal arms

Case reports

Case 1 was a girl born in head presentation The pregnancy had been uneventful but intrauterine asphyxia in the final stage of labour prompted assistance of delivery with vacuum extraction The observed amount of amniotic fluid appeared normal The forehead of the baby was found to be deformed on the right side by a broad furrow running parasagittally with a laterad slope toward the temple A much shallower but otherwise similar concavity was observed at the corresponding site on the left side The Apgar score at one min was 7 The baby appeared irritable and was rather pale

Radiographic examination of the skull one hour after birth failed to demonstrate the slight deformity on the left side but clearly showed a right sided impression of the frontal squama and traumatic lesions of the soft tissues Several views were obtained to evaluate the degree and extent of the impression These excluded fragmentation of the bone and showed that the concavity was limited by the coronal suture and the midline (Fig 1) A swelling and a surrounding circular groove extending across the posterior part of the sagittal suture had obviously been shaped by the suction of the vacuum cup and the pressure by its brim Another swelling first situated outside the right parietal bone resembled a kephalhematoma but on re examination a few hours later it proved to be a subgaleal hematoma it had in the meantime moved to the left side of the skull and extended into the neck displacing the left auricle laterad Despite these swellings the soft tissues in the concavity of the bone were on both occasions normal in thickness (Fig 2)

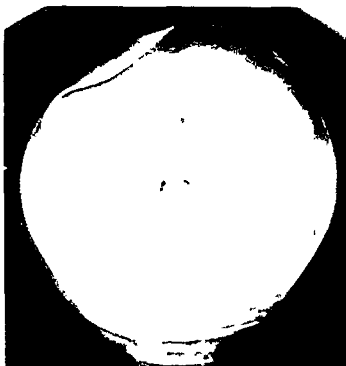
The limbs of the baby were normal and the shape of the feet did not correspond to that of the forehead but when the right wrist was placed against the skull its dorso radial surface proved to fit exactly into the right frontal impression (Fig 3) The other wrist similarly matched the slight deformity on the left side

The subgaleal bleeding caused no trouble except transient anemia Neurologic examination revealed nothing abnormal and the skull deformity decreased without treatmement A minor concavity on the right side was still visible after 9 months but one year later only slight flattening persisted General growth and development were unremarkable

Case 2 was a boy born in a foot presentation and had a parietal deformity on the left side At the end of delivery 3½ hours after onset of labour his arms had been brought down from a position along the head The observed amount of amniotic fluid was normal The Apgar score was 5 at one min but improved to 9 in 2 min

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a



b

Fig 1 Case 1 Right sided congenital impression of frontal squama

Radiographic examination of the skull immediately after birth showed a deep impression of the posterior part of the left parietal bone The concavity was about 5 cm in diameter and was limited by the lambdoid and sagittal sutures The bone was not fragmented and no swelling of the soft tissues existed (Fig 4a)

The general condition of the baby appeared excellent and no treatment was given When re-examined 22 hours later the deformity had already regressed (Fig 4b) but the external concavity was still visible and proved to correspond perfectly with the dorsal surface of the left wrist (Fig 4c) The deformity disappeared in a couple of weeks Subsequent development has been unremarkable

Discussion

Impression of part of a calvarial bone is a relatively uncommon variety of the skull deformities encountered in newborns When found at birth it is usually attributed to fracture sustained during delivery Such birth fractures may be caused either by obstetrical instruments or by the bony portions of the birth canal e g the normal promontory or pubic bones an exostosis of the spine or some prominence due to deformity of the pelvis On the other hand similar impressions may be the residues of prenatal fractures caused by abdominal trauma to the mother during the pregnancy (AXTON & LEVY 1965 ALEXANDER & DAVIS 1969)

The impression fractures of the skull in utero like those occurring early in infancy usually lack macroscopic fragmentation of the bone and callus production This type of injury widely referred to as a ping pong ball fracture thus causes osseous abnormalities similar to those as may result from moulding of the skull in utero Deformities of either origin have exceptionally been found prenatally at Caesarean section (BARR) vaginal palpation (GUHA RAY 1976) or radiographic examination (RAWL 1957 ALEXANDER & DAVIS) but calvarial impression by the fetal limbs seems never to have been observed before birth Conclusive evidence of such an impression can be obtained after birth only if the site and shape of the deformity are characteristic enough to disclose the causative former position of the limbs

The possibility that the feet may cause impression of the skull was illustrated by CAFFEY (1950) by a drawing based on the observations made by BROWNE Since that drawing has been reproduced by CAFFEY in all subsequent editions of his text book and by various other authors as well it has long been wellknown but surprisingly few original observations are on record A search of the literature revealed only 2 further cases in which the calvarial bones were claimed or suggested to have been deformed in utero by the fetal feet (BERNHEIM

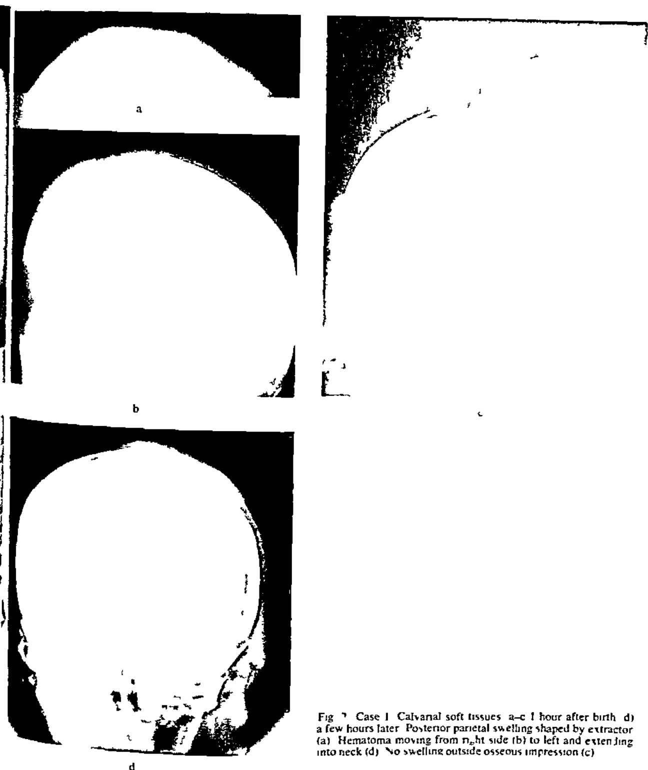


Fig 7 Case I Calvarial soft tissues a–c 1 hour after birth d) a few hours later Posterior parietal swelling shaped by extractor (a) Hematoma moving from right side (b) to left and extending into neck (d) No swelling outside osseous impression (c)

et coll 1976 WAGNER et coll 1968) In a case reported by KYLE & JENKINSON (1973) a frontal impression detected after delivery was claimed to have been produced by the humerus of an arm found in the second stage of labour to prolapse in front of the head The delivery had occurred spontaneously before treatment could be given and a clinical diagnosis of fracture seems to have been taken for granted Although radiologic findings were considered to lend support to this diagnosis the evidence given seems equally consistent with prenatal moulding by the arm

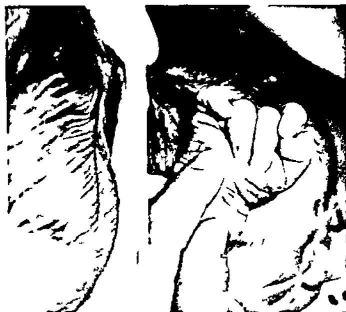


Fig 3a Fig 3b



Fig 4a Fig 4b



Fig 4c

Fig 3 Case 1 a) External shape of deformity b) Position of arm fitted into deformity

Fig 4 Case a) Immediately after birth Impression of left parietal bone No swelling of overlying soft tissues b) 22 hours later Regression of deformity c) Position of arm fitted into deformity

In view of the difficulties in recognizing the origin of a congenital calvarial impression the few deformities on record attributed to moulding by the fetal limbs are unlikely to reflect the true incidence of such deformation Both the present cases were found in the course of one year They thus suggest that prenatal impression of the skull by the fetal limbs is not an extreme rarity and they confirm that the limb involved can be an arm as well as a leg Although the position of the arm responsible for the deformity was observed during delivery in only one of the cases the diagnosis was established in both by demonstrating that a causative position could be reproduced after birth This diagnostic manoeuvre was prompted by the radiologic findings

The main purpose of the radiography was to exclude a bone fragment that might have injured the brain but also the appearance of the soft tissue proved informative The absence of a hematoma in both cases the concavity of the deformed bone in both cases did not support the initial assumption of a fracture It cannot be excluded with certainty that the instantaneous impression without fragments characterizing a ping pong ball fracture may

cationally not be accompanied by bleeding However this was considered unlikely because in the present cases of undisputable fracture of this type sustained after birth a local hematoma has invariably been demonstrable

According to CAFFEY cranial depression present at birth and not associated with edema or hemorrhage of the overlying soft tissues are usually due to long standing faulty fetal position rather than to recent birth injury In the available original reports attributing calvarial moulding to the fetal limbs the soft tissues were not specifically mentioned and radiographic examination was carried out only in the case reported by WAGNER et coll Their findings were illustrated by an a p view of the skull showing biparietal impressions resembling ping pong ball fractures but the soft tissues are not visible and the differential diagnosis was not discussed The observations made in the present cases are consistent with the opinion expressed by CAFFEY and strongly suggest that radiologic evaluation of the soft tissues may afford a valuable clue to the diagnosis Although experience is still insufficient to assess the validity of this statement the finding of normal soft tissues outside a congenital impression of the skull should prompt an attempt to reproduce an explanatory position of the limbs

It appears likely that a limb responsible for prenatal moulding has been kept in the causative position for some time if not habitually before birth It is known that improper position of the fetus may reflect insufficiency of intrauterine space due for example to oligohydramnios or some major malformation or tumor Since no such abnormality existed in the present cases it is not possible to explain why the arms of these fetuses were pressed against the skull in utero

SUMMARY

Two cases are reported in which congenital impressions of the skull were explained by the position of the arms in utero

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ACCURACY OF ECHOVENTRICULOGRAPHY AS COMPARED WITH COMPUTER TOMOGRAPHY IN CHILDREN

U ERASMIE J HANSON and H RINGERTZ

Computer tomography (CT) is in many respects the ideal method for examination of the cerebral ventricles The method is non invasive without risk of serious complications It is comfortable for the patient and gives a clear conception of the size and form of the cerebral ventricles as well as of the brain and subarachnoid space However a CT examination is rather expensive and time consuming and involves a radiation dose to the patient Furthermore in children sedation is often required and occasionally general anesthesia (ERASMIE & BERGSTRÖM 1979)

A mode echoventriculography (echo VG) is an alternative examination method for the cerebral ventricles (SJÖGREN 1967) It does not provide the same detailed information as CT but gives a conception of the size of the ventricles and is much less time consuming and expensive It involves no radiation hazard These properties seem to make echo-VG suitable as a screening method Most previous evaluations of echo VG in comparison with encephalography (SJÖGREN et coll 1968 HANSON et coll 1975 KRIJGSMAN 1977) and with CT (HANSON et coll SKOLNICK et coll 1979) have indicated a good correlation between the different methods at least regarding the size of the lateral ventricles although less favourable results have also been reported (SYNEK et coll 1976) The purpose of the present investigation was to further evaluate the accuracy of echo-VG in children as compared with CT An attempt was also made to find out if some disorders were more likely than others to give less accurate results and if so to analyse the reasons as well as their clinical consequences

Material and Methods

In a series of 144 children 70 girls and 74 boys (0 to 15 2 years median age 2 2 years) echo-VG and CT examination were as a rule performed the same day The interval between the examinations did not exceed one week in any of the cases A Mark I EMI scanner with a 160×160 matrix at 120 kV was used for the CT examinations The slice thickness was 10 mm for children over one year and 5 mm for children below one year On the CT examination the anterior horn index and the body index were determined —the anterior horn index=the distance between the lateral walls of the anterior horns of the lateral ventricles divided by the largest internal skull diameter (LINDGREN 1951) and the body index=the width of the lateral ventricles at the body divided by the internal diameter of the skull at the same site (HANSON et coll)

The echo-VG was performed with a Siemens Echo encephalograph T Krautkrämer system type USIP 11 E using a piezoelectric crystal of 2 MHz The distance between the lateral walls of the lateral

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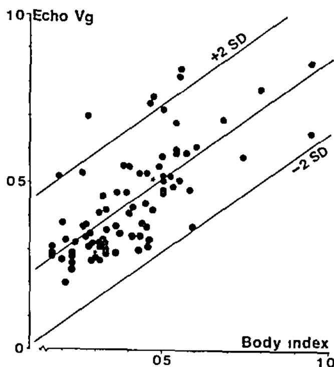


Fig. 1. Distribution of echo VG findings and CT body index in the 89 cases in which both were observable. ●=one case, *=two cases. Regression line with ± 2 SD is given (r=0.725).

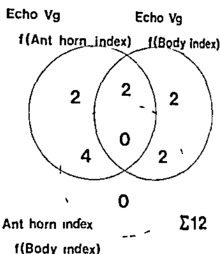


Fig. 2. Venn diagram. Distribution of the 12 cases that deviate more than 2 SD in the regression between the ventricular indices.

ventricles a few centimeters above the external auditory meatus was determined. The lateral ventricular index (Sjögren's index) was calculated by dividing this distance with the external diameter of the head (including bone and skin) at the same site (SJÖGREN et coll., HANSON et coll.). The examinations were usually carried out by one of three experienced technicians.

Computerized statistical calculations were performed with standard formulae and computer programs.

Results

The number of cases in which it had been possible to calculate the different indices, the minimum and maximum value for each index, average value, standard deviation (SD) and median value are given in Table 1.

The material divided in groups depending on the distribution of observable indices with average age ± SD and distribution of children over and under the median age for each group appears in Table 2.

The echo VG was successful in 86 per cent of all cases, in 97 per cent for patients below 2.2 years and in 75 per cent for patients over 2.2 years. On CT the anterior horn index was measurable in 9[illegible] per cent, in 96 per cent for children below 2.2 years and in 83 per cent for children over 2.2 years. The body index was obtainable in 67 per cent, in 83 per cent for children below 2.2 years and in 51 per cent for children over 2.2 years.

The distribution in Table 2 of age relative to observable indices deviates with high significance from random (p<0.001). The smaller the child the greater the probability to register all indices with both methods.

Besides dilatation of the ventricles additional findings were recorded in 18 cases. Collapsed ventricles on CT were observed in 9 cases aged 8.3±3.5 years

Table 1

Number of patients in which the different indices were observable and statistical findings for each index

Index	Number	Minimum	Maximum	Mean	SD	Median
Ant. horn	[illegible]	0.10	0.93	0.38	0.14	0.34
Body	97	0.16	1.00	0.40	0.17	0.36
Echo-VG	[illegible]	[illegible]	0.86	0.41	0.15	0.35

Table 2

Distribution of observable indices in 144 patients in relation to the median age 2 2 years For each combination of observable indices is given average age and SD of the patients

Ant horn index	Body index	Echo VG index	Number <2 2 years	Number >2 [illegible] years	Age Mean	Age (SD)
×	×	×	57	31	3 1	(4 1)
×	–	×	11	15	4 6	(4 3)
–	–	×	[illegible]	8	6 0	(4 [illegible])
×	×	–	[illegible]	6	8 3	(5 6)
×	–	–	0	8	10 6	(4 [illegible])
–	–	–	0	4	7 1	([illegible] 0)

× = Observable index
– = Not observable index

Only asymmetry in 2 cases asymmetry with cyst or hygroma in 2 cases cyst or hygroma in 2 additional cases without asymmetry midline deviation on echo-VG in 2 cases (3 and 6 mm) and finally missing CT sections in one case The age of the last 9 cases was [illegible] 9±4 7 years which represents a significant deviation from the group with collapsed ventricles (p<0 05) The 88 patients in which all 3 indices could be calculated had higher average indices than the rest of the patients Their anterior horn index [illegible]±0 13 and echo VG index 0 44±0 16 deviated highly significantly (p<0 001) from the corresponding values 0 30±0 12 and 0 33±0 10 respectively of the remaining patients

The overall correlation coefficients between the 3 indices as well as corresponding coefficients for patients under and above the median age and girls and boys are given in Table 3

No difference in any respect could be demonstrated between patients with echo VG and CT examination the same day and those with one to ten days between the examinations

The equations for the linear regression between the 3 indices and corresponding residual deviations are listed in Table 4 Twelve patients with a deviation more than 2 SD from the regression lines between CT and echo VG indices in Table 4 are shown in the Venn diagram in Fig 2 All of them had abnormal lateral ventricles Six of them deviated more than 2 SD from the regression lines between body index and echo VG index (Fig 1)

Discussion

The brain and the cerebral ventricles surrounded by the skull bones is no ideal object for ultrasound examination The skull bones may be too thick and absorb too much energy to permit recording of echoes from the ventricles In children especially in newborns and infants the conditions are more favourable as the cranium is thinner and recording of the ventricular echoes is consequently easier and more precise It is quite possible to perform B mode echo VG in children (ADAPON et coll 1965 SKOL

Table 3

Correlation coefficients (r) between CT and echo-VG indices Number of patients within parentheses

		Echo-VG/ ant horn index	Echo-VG/ body index	Ant horn index/ body index
All		0 617 (113)	0 7 5 (89)	0 779 (96)
Under	years	0 609 (67)	0 7[illegible]4 (58)	0 815 (59)
Above	years	0 604 (46)	0 673 (31)	0 6 6 (37)
Girls		0 595 (56)	0 731 (47)	0 643 (49)
Boys		0 686 (57)	0 746 (4)	0 884 (47)





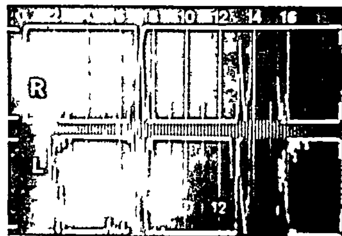


Fig 3 CT and echo-VG from a 4-month-old girl with dilatation of posterior horn (anterior horn index 0 29 body index 0 78 and echo-VG 0 0)

Fig 4 CT and echo-VG from a 4-month-old girl with a cystic malformation in her right hemisphere (anterior horn index 0 4 body index not measurable and echo VG 0 69)

SICK et coll) which gives more detailed information than A scan but inferior quality as compared with CT In our experience B scan is much more difficult to handle than A scan requiring a cooperative or sedated patient Therefore CT has been preferred for detailed examinations and A mode echo VG for screening and follow up examinations In the present series the echo VG was successful in 97 per cent of the patients below 2 2 years but only in 75 per cent of the patients over 2 2 years In the younger age group the mean ventricular size was somewhat larger than in the older age group—a fact that may be a contributing cause for the better result in the younger age group On CT it was often difficult to discern the body and occasionally the anterior horns of slender lateral ventricles In a few cases movement artefacts complicated the evaluation Thus it was possible to calculate the body index only in 67 per cent of the cases and the anterior horn index in 90 per cent The result was better for children below than over 2 2 years The better result in the younger age group is probably due to the fact that the mean ventricular size was larger in this group and thus the ventricles were easier to delineate Even in the not measurable cases on CT it was possible to evaluate the size and shape of the ventricular system and to demonstrate or exclude hydrocephalus This was evidently not the case in echo VG

Previous reports have indicated good accuracy of echo VG in children (SJOGREN et coll) and in a mixture of children and adults (HANSON et coll) while SYNEK et coll reported less favourable results

Table 4

Equations for the linear regression between CT and echo VG indices and corresponding residual deviation

Equation	Residual deviation
Echo-VG = 0 691 × ant horn index + 0 144	0 1[illegible]
Echo-VG = 0 7[illegible]1 × body index + 0 151	0 10[illegible]
Ant horn index = 0 650 × body index + 0 164	0 0[illegible]



Fig 5 CT and echo-VG from a 3-month-old boy with dilatation mainly of anterior and posterior horns (anterior horn index 0 68 body index 0 43 and echo-VG 0 30)

in adults This seems to indicate better accuracy in younger patients It is well known that echoes are more easily obtained the younger the patient is The recording is also facilitated by large ventricles SYNEK et coll recorded echoes at a more frontal site than SJÖGREN et coll HANSON et coll and KRUGSMAN It seems that the ventricular wall in the body region reflects the ultrasound better which was also the conclusion made by KRUGSMAN Be... s CT is a more suitable method for comparing ... accuracy of echo-VG than encephalography as ... air might distort the *ventricles* (LINDGREN JIR... T 1956 OBERSON et coll 1969 OIGAARD 1971 ... et coll 1972 PROBST 1973 MOSELEY et coll ...7) In the present series no difference existed in ... correlation between echo-VG and the anterior horn index in the different age groups The correlation between echo-VG and the body index was only slightly higher in the younger than in the older age group The difference was not statistically significant and did not exceed the difference between the two sexes where no difference could be expected SYNEK & REUBEN (1976) used a planimetric method in a single suitable CT section in order to assess the size of the ventricles on CT However planimetry is an elaborate method and it remains doubtful whether any advantages could be achieved compared with linear measurements Therefore the latter approach was preferred Comparing the two CT indices with the echo-VG index it must be borne in mind that the different indices are measured in different ways and represent different parts of the lateral ventricles In the anterior horn index the width of the anterior horns is compared with the largest internal skull diameter The index will consequently fall below 1 0 even if there is no brain parenchyma at all at the site of the anterior horns In echo-VG the width of the lateral ventricles was compared with the skull diameter including skin and bone while in the body index it was compared with the internal skull diameter The echo-VG index is less clearly defined as the position of the transducer was changed until the best possible ventricular echoes were found Nevertheless the echo-VG index and the body index were measured in the same region thus it is natural that the correlation between them should be better than between echo-VG and anterior horn index

An analysis of 12 cases with a deviation of more than 2 SD from the regression lines between Sjögren s index anterior horn index and body index showed that all of them had abnormal lateral ventricles (Fig 2) In 7 cases with a localized dilatation of the posterior horns the anterior horn index and the body index were low while Sjögren s index was high (0 29 0 28 and 0 70 respectively in the case shown in Fig 3) because the transducer had to be placed in a more posterior position than usual in order to receive distinct echoes The 6 cases with a deviation more than 2 SD between the regression lines between body index and echo-VG index are all of this type (Fig 1) This explains why all 6 deviating cases have higher echo-VG index than body index as in the figure Thus no case was underestimated more than 2 SD with echo-VG In 3 cases both the anterior and posterior horns were dilated but a near normal width of the body of the lateral ventricles (Fig 5) The anterior horn index is high (0 68) while the body index is only slightly elevated (0 43) and Sjogren s index normal (0 30) In one case with a localized dilatation of the anterior horns the anterior horn index was high (0 76) but not the body index (0 31) or Sjogren s index (0 35) In one case (Fig 4) a cystic malformation in the right hemisphere caused a high

Sjogren s index (0 69) in comparison with the anterior horn index (0 43) The body index was not measurable The asymmetry and lack of midline structure was observed in echo VG and a malformation was suggested Thus in all these 12 cases the discrepancy between echo VG and CT was ostensible and explained by the anatomic shape of the lateral ventricles and different sites of measurement The anatomic information obtained from the CT examination facilitates the evaluation of the echo VG examination An initial CT examination is therefore very valuable in follow up examinations with echo VG

Conclusions

(1) The accuracy of echo VG as compared with CT is fairly good in children

(2) For an accurate anatomic examination of the cerebral ventricles CT is the method of choice

(3) Discrepancy between echo VG and CT indices is often explained by the anatomic shape of the lateral ventricles and different sites of measurements

(4) Echo VG is useful as a screening method and for follow up examinations in children

SUMMARY

The accuracy of echoventriculography (echo VG) using CT findings as a reference has been examined in 144 children Lateral ventricular index on echo VG was compared with anterior horn and body indices on CT The correlation coefficient was 0 617 and 0 725 respectively Twelve cases with a deviation exceeding 2 SD in the regression between the indices were analysed The conclusion is that echo-VG is fairly accurate and useful as a screening method and for follow up examinations in children

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COMPUTER TOMOGRAPHY IN SUPERIOR SAGITTAL SINUS THROMBOSIS

JAN BRISMAR

Thrombosis of the cerebral veins and venous sinuses is a comparatively rare condition which may develop either secondary to an infectious lesion in the vicinity of the venous structures (septic throm bosis) or without such a connection (primary or aseptic thrombosis) Aseptic thrombosis has been reported as a complication to pregnancy in various inflammatory or tumorous conditions as well as in marantic states but may also occur without any demonstrable etiologic factor A detailed review of the literature is given in a monograph by KALBAG & WOOLF (1967) The aim of the present report is to discuss the diagnostic problems on the basis of 4 cases examined by computer tomography (CT) 3 of them also by cerebral angiography

Methods Standard serial cerebral angiographic techniques were employed CT was performed using an EMI 1010 head scanner with 160×160 matrix and 10 mm nominal section thickness For contrast en hancement 100 ml Isopaque Cerebral (280 mg I/ml) was given in slow intravenous injection directly followed by scanning

The case histories as well as the clinical and radiologic findings are presented in the Table

Discussion

As evident from the present cases as well as from the literature (LEMMI & LITTLE 1960 KALBAG & WOOLF GABRIELSEN & HEINZ 1969) the symptoms and signs associated with a superior sagittal sinus thrombosis may vary considerably The mortality rate has been estimated to be 30 per cent (KENDALL 1948) The real mortality is probably considerably lower as the clinical diagnosis especially in less severe cases is difficult while the autopsy diagnosis is easy The clinical course and the prognosis are determined by the development of collateral venous channels In this context the location and extent of the thrombosis anatomic variations as well as the rate of evolution of the condition will be of crucial importance (KALBAG & WOOLF)

Headache is the most common single symptom and often precedes the other symptoms by hours days or even months (KALBAG & WOOLF) In the present series 2 patients had headache and vomiting for a month before onset of other symptoms The headache may be associated with facial neuralgia as in case 3 Following the acute episode of cerebral venous thrombosis headache may remain as an iso- lated symptom for years (HUHN 1961) In case 2 headache persisted 4 months after disappearance of other symptoms

Convulsions either generalized or Jacksonian seizures are common Focal seizures in these cases have a tendency to spread (BIEMOND 1935) as dem onstrated by the only patient in the present series exhibiting seizures (case 2)

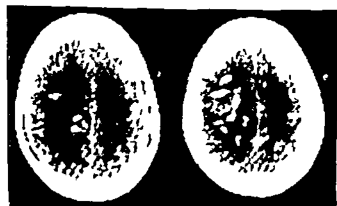
Disturbance of the motor function is frequently encountered it occurred in 2 of the present patients (cases 1 and 2) Ascending hemiplegia due to suc cessive spread of the thrombosis has been pointed

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Table

Summary of case histories clinical and neurologic findings in 3 patients with angiographically confirmed and one patient with possible thrombosis of the superior sagittal sinus

Case No	Sex age previous diseases	History on admission	Clinical signs	Ophthalmoneurologic findings	Brain scintigraphy	Computer tomography
1	F 43 previously healthy	4 w headache vertigo vomiting Day of admission paresthesia left side weakness	Left hemiparesis deviation conjugee to right left central facial palsy	Normal	—	Extensive bilateral intracerebral hemorrhages with surrounding low attenuating region
2	F 46 Crohn s disease and healed pulmonary tuberculosis	4 w headache fever vomiting followed by epileptic seizures (After admission transient loss of muscular strength in right hand)	Normal neurologic findings	Normal	Normal 1 w before admission 3 w later positive at site of CT lesion	Small right frontal hemorrhage with surrounding edema In 17 d resorption of hemorrhage (Fig 2a)
3	M 62 previously healthy	5 d severe headache round right eye and cheek 2 d high fever	Normal neurologic dental and ENT findings	Normal on admission 4 w later bilateral papilledema (2 D) with hemorrhages deteriorating following month	—	Probably normal
4	F 68 diabetes mellitus	3 w confusion abdominal pains vomiting minor seizures sudden deterioration with persistent loss of consciousness	Normal neurologic findings before loss of consciousness	—	1 w before loss of consciousness findings consistent with right frontal tumour	After loss of consciousness right frontal malignant tumour Extensive left sided hemorrhage with surrounding edema (Fig 4)



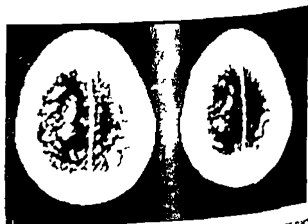


Fig 1 Case 1 Sudden onset of left sided hemiparesis CT on admission Bilateral multiple intracerebral hemorrhages surrounded by low attenuation regions (left) with moderate enhancement (right) At angiography occlusion of the anterior part of the superior sagittal sinus

Table (*cont.*)

Angiography	Further course
Bilateral frontopa rietal masses occlu sion of frontoparietal part of superior sagittal sinus	Progressive deterioration death 2 d after admission in cerebral herniation Autopsy confirmed diagnosis
… after admission Partial thrombosis of posterior third of superior sagittal sinus (Fig. b)	Gradual improvement but some remaining headache
… later Thrombosis of posterior …/3 of superior sagittal sinus (Fig 3)	Almost complete disappearance of pains and papilledema in 6 m
	Death 3 d after admission No autopsy

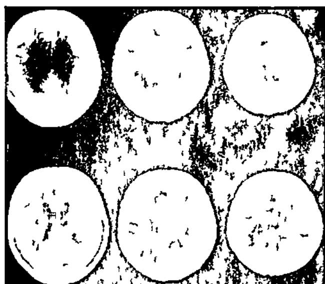


Fig ?a

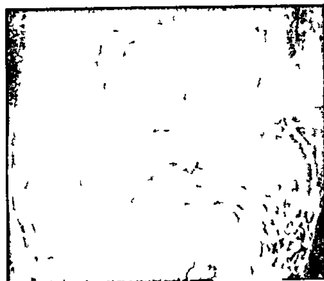


Fig 2b



Fig 3

Fig. … Case … Epileptic seizures following one month s history of headache a) CT (upper row) rightsided hemorrhage sur rounded by region of low attenuation Two weeks later a second CT (lower row) demonstrates resorption of the hemorrhage At the same time abnormal at brain scintigraphy with $^{99}Tc^m$ per technetate b) Oblique a p view Carotid angiography another week later Defective filling of posterior part of the superior sagittal sinus and irregular tortuous cortical veins

Fig 3 Case 3 One month after onset of severe facial pains and progressive papillary edema normal CT examination Five months … left-sided carotid angiography Occlusion of posterior part of superior sagittal sinus with collateral circulation through tor tuous cortical veins

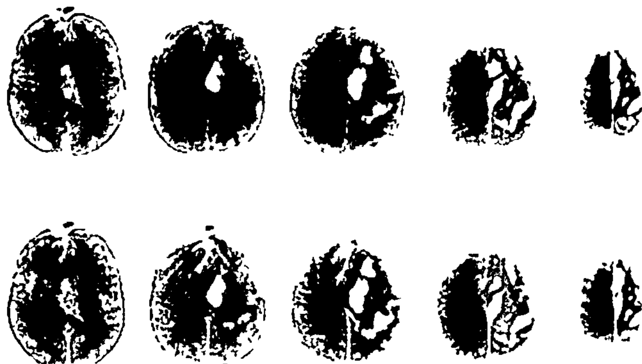


Fig 4 Case 4 One week's symptomatology consistent with a brain tumour Right sided frontal lesion found at $^{99}Tc^{m}$ brain scintigraphy CT one week later upper row before lower row following i v contrast medium In addition to findings consistent with a malignant frontal right sided tumour with a rim enhancement also a large left sided low attenuation region with multiple hemorrhages

out to be a typical form of paralysis among these patients (BONNET & GAILLARD 1942) The paralyses may vary in extent and intensity may change from hemiplegia to monoplegia or the reverse or from side to side (DUBOIS 1956) Case 1 had a progressive paralysis case 2 a brief period with loss of muscular strength in the right hand as well as a rightsided facial palsy It has been suggested that convulsoparalytic manifestations indicate that the thrombosis is no longer limited to the superior sagittal sinus but has spread into the cortical veins (KALBAG & WOOLF)

Cranial nerve symptoms or signs are normally not observed in cases with a thrombosis limited to the superior sagittal sinus and indicate thrombotic involvement of the cavernous sinus (N III V VI) or the jugular bulb (N IX X XI) also

In some cases as in case 1 early signs of raised intracranial pressure rapidly progress into lethargy and coma

Papilledema the most evident sign in case 3 was present in 10 of 18 patients in the material of KALBAG & WOOLF

The variable symptomatology in cases with a thrombosis of the superior sagittal sinus makes the clinical diagnosis difficult especially in the absence of known predisposing factors such as a puerperal state or oral contraceptives (BUCHANAN & BRAZINSKY 1970) Thus in none of the present cases was the diagnosis of thrombosis clinically contemplated before angiography or (case 1) CT In vivo thrombosis can be conclusively diagnosed only by means of angiography demonstrating a partial (case 2 Fig 2b) or complete (case 1 case 3 Fig 3) occlusion of the sinus as well as tortuous irregular cortical veins In recent years CT has in many centers replaced angiography as the primary radiologic procedure in the evaluation of neurological conditions with a symptomatology like the one encountered in cases with a thrombosis of the superior sagittal sinus Therefore it is of interest to establish whether the CT findings in such patients are characteristic so as to suggest a sinovenous occlusion indicating angiography

A few reports concerning the CT appearance of intracranial sinovenous thrombosis have appeared (BUONANNO et coll 1978 KINGSLEY et coll 197- WENDLING 1978) WENDLING described one case

an 18 month old child with a thrombosis of the great vein of Galen and the straight sinus who at CT exhibited increased attenuation in the region of these occluded vessels

BUONANNO et coll reported on 11 patients with intracranial sinovenous occlusion 6 of them with a nonseptic non infectious venous thrombosis and an acute clinical onset In 5 patients the thrombosis involved the superior sagittal sinus in the 6th patient both middle cerebral veins were thrombotized. Three of these 6 cases presented at CT with distinct pathologic findings in one case multiple bilateral intracerebral hemorrhages in one a solitary intracerebral hematoma and in the third a low attenuation region exhibiting contrast enhancement. In 3 of the 6 patients the ventricles were small in 3 gyral enhancement was observed and in 2 an empty triangle i e a non enhanced region at the site of the superior sinus in sections perpendicular to the sinus posteriorly If occurring on different levels this latter abnormality was considered pathognomonic confirming the presence of an iso attenuating clot in the sinus In only one of these patients was the CT examination considered normal

KINGSLEY et coll presented 5 patients with angiographically confirmed primary aseptic thrombosis of the superior sagittal sinus All 4 patients scanned within the first week after ictus had either small ventricles on the initial scan or ventricular enlargement on subsequent scans One patient had slight swelling of one hemisphere and one had bilateral low attenuation areas with hemorrhage

It is a well known fact that multiple intracranial hemorrhagic infarcts are often found at autopsy in cases with extensive sinovenous thrombosis (KALBAG & WOOLF) It is therefore not surprising that CT in some cases with a thrombosis of the superior sagittal sinus demonstrates bilateral multiple hemorrhages surrounded by low attenuation regions This was the case in case1 (Fig 1) In case 4 a thrombosis would explain the otherwise confusing CT findings (Fig 4) as well as the rapid impairment in the condition of the patient The finding of multiple or even bilateral intracranial hemorrhages in a non traumatic patient is strongly indicative of the presence of thrombosis of the superior sagittal sinus In cases with a single intracerebral hematoma surrounded by a low attenuation region as in case 2 (Fig 2) the probability of an underlying thrombosis is much less However it should be borne in mind that the possibility exists

Whether the ventricles are slightly compressed is often difficult to determine from a single CT examination In case 1 the extensive hemorrhages compressed the ventricular system (Fig 1) cases 2 and 3 had normal ventricular size at the initial scan as well as at subsequent examinations However the serial CT examinations reported by KINGSLEY et coll indicated that a sagittal sinus thrombosis often causes a compression of the ventricles The finding of a small ventricular system though highly unspecific should therefore call attention to the possibility of a thrombosis of the superior sagittal sinus

No gyral enhancement increased attenuation along the occluded venous channels or a non enhanced region was found in the present series

It is debatable whether the diagnosis of a sinovenous occlusion has any major therapeutic implications The frequent association between sinovenous occlusions and hemorrhagic infarcts has led to a reluctance to use anticoagulants GETTELFINGER & KOKMEN (1977) reported 3 patients treated with anticoagulants for a sinus thrombosis 2 died from hemorrhagic intracerebral complications It was concluded that the risk of untoward complications was great enough that one should rely on more conservative therapy with antiedematous agents and anticonvulsants

SUMMARY

Three angiographically confirmed cases and one possible case of aseptic superior sagittal sinus thrombosis had CT findings ranging from apparently normal to single or even bilateral multiple intracerebral hemorrhages surrounded by low attenuation regions The latter finding in particular suggests a possible superior sagittal sinus thrombosis

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COMPUTER TOMOGRAPHY IN THE EVALUATION OF SUBARACHNOID HEMORRHAGE

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The introduction of computer tomography (CT) in 1973 has changed most aspects of conventional neuroradiology The impact of the new method has been great and the indication for most if not all conventional neuroradiologic procedures has been modified or even considerably changed Thus encephalography has almost entirely been replaced by CT Cerebral angiography still is indispensable for the examination of patients with subarachnoid hemorrhage as the size and shape of an arterial aneurysm cannot be assessed in detail by CT scanning Angiography on the other hand seldom gives any detailed information about the volume and extension of a possible intracerebral hematoma following rupture of an aneurysm nor does it reveal cisternal blood or a penetration of blood into the cerebral ventricles

A single angiography of the relevant vessel has been favoured over a complete angiographic examination as the initial procedure (KENDALL et coll 1976) on the argument that a new bleeding is seldom due to a rupture of a second aneurysm when multiple aneurysms are present The initial angiography can be limited to the vessel harbouring the aneurysm when a definite location of the aneurysm is indicated clinically or if in other cases the site of the aneurysm could be more adequately determined This would be of advantage if the modern trend to operate saccular intracranial aneurysms at an early stage after a subarachnoid bleeding will be the dominating surgical policy

In order to evaluate CT in subarachnoid hemorrhage a review of 68 consecutive patients has been performed as an extension of a previous report (LILIEQUIST et coll 1977) Some of the patients are included in both reports Special interest has been focused upon the time relationship between the initial bleeding and the persisting appearance of blood in the cisterns and also upon the possibility offered by the new method to reveal infarctions

Material

The material consisted of 68 consecutive patients whose sex and age distribution does not diverge from what is commonly found in a population of patients with subarachnoid hemorrhage (Table 1)

All patients were referred on clinical suggestion of subarachnoid bleeding all had blood in the CSF at lumbar puncture In all patients CT scanning was the first diagnostic procedure followed by cerebral angiography in all but 3 patients In one of these 3 patients CT demonstrated a cerebellar hemorrhage which was evacuated in another the intracranial circulation abolished at the time of angiography due to a huge intracerebral hematoma the third patient died before angiography could be performed In these 3 cases the hematoma could subsequently be shown not to have been caused by a ruptured aneurysm

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Table 1

Sex and age distribution of 68 patients with clinical signs of subarachnoid hemorrhage examined with CT and cerebral angiography

Age (years)	Women	Men	Total
–20	1	1	2
20–29	–	2	2
30–39	4	4	8
40–49	9	8	17
50–59	10	11	21
60–69	11	2	13
70–	2	3	5
Total	37	31	

Table 3

Site and number of aneurysms in 52 patients with subarachnoid hemorrhage caused by rupture of aneurysm

Site	Number
Middle cerebral artery	19
Anterior communicating artery	13
Posterior communicating artery	20
Pericallosal artery	4
Basilar artery	2
Posterior inferior cerebellar artery	6
Anterior inferior cerebellar artery	1
Ascending frontal artery	1
Total	66

One vessel angiography was carried out in 5 patients, two vessel angiography in 15 and three vessel angiography in 32 patients

In 10 patients no aneurysm could be found at angiography or autopsy In 8 of these three vessel angiography was carried out in one two vessel examination and in one a carotid angiography only

In 55 of the 68 patients at least one intracranial arterial saccular aneurysm was demonstrated One patient was excluded from the series since gross artifacts at CT scanning prohibited a detailed analysis In 2 patients an intracerebral hematoma was evident on CT not caused by the aneurysm documented at angiography For a further analysis 52 patients with subarachnoid hemorrhage caused by confirmed aneurysm rupture remain (Tables 2 3)

Results

The time relationship between the initial bleeding and CT evidence of blood in the CSF spaces in the 52 patients is illustrated in Fig 1

Table 2

Number of aneurysms in 52 patients with subarachnoid hemorrhage caused by rupture of aneurysm

	No of cases	No of aneurysms
	41	1
	8	2
	3	3
Total	52	66

In the 32 patients who were examined within 2 days after the bleeding episode blood could be identified in the cisterns in 27 In another 11 patients 12 examinations were carried out within 3 to 5 days 6 of these patients had blood in the cisterns Among the remaining 9 patients examined after the elapse of 5 days blood in the cisterns was apparent in only one patient Altogether 22 repeat examinations were performed after the elapse of 5 days Blood was demonstrated on one examination only in a patient with an aneurysm on the posterior inferior cerebellar artery with clinical indication of repeat bleeding

In 31 patients with one or several aneurysms and blood in the cisterns at CT scanning the ruptured aneurysm was identified In search for a diagnostic feature related to the site of the aneurysm the distribution of the blood in the cisterns was analysed in those patients (Table 4)

In 7 of 8 cases with middle cerebral artery aneurysms blood was found in one or both Sylvian fissures (Fig 2) and all cases with anterior communicating artery aneurysm had blood in the interhemispheric fissures and suprasellar cisterns (Fig 3) In posterior communicating artery aneurysm 7 of 8 had blood in the suprasellar cisterns and 6 of 8 also in the ambient cistern Both pericallosal artery aneurysms had blood in the interhemispheric fissure and the pericallosal cistern Aneurysms located within the posterior cranial fossa as well as one aneurysm on the posterior communicating artery had blood in the pontine and pontocerebellar cisterns

Among the 52 patients with aneurysms 18 had an intracerebral hematoma Hematomas in the frontal lobe were caused by rupture of an anterior com

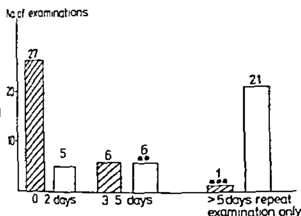


Fig 1 Blood in subarachnoid cisterns demonstrated at CT after the initial bleeding Hatched Blood in cisterns Unhatched No blood in cisterns Location of the aneurysm 1 anterior communicating artery 1 posterior communicating artery 2 pericallosal artery 1 posterior inferior cerebellar artery 1 middle cerebral artery 3 posterior communicating artery 2 posterior inferior cerebellar artery posterior inferior cerebellar artery * 2 repeat bleedin



Fig 2 Aneurysm of middle cerebral artery Blood in both Sylvian fissures predominantly on the side of the aneurysm

Fig 3 Aneurysm of anterior communicating artery Blood in the interhemispheric fissure and suprasellar cisterns as well as a focal midline hematoma

municating artery aneurysm or (in one case) a pericallosal artery aneurysm Hemtomas in the temporal lobe in the Sylvian fissure or in the basal ganglia were found with aneurysms on the middle cerebral artery A small hematoma in the midline presumably in the cisterna lamina terminalis was a characteristic finding in anterior communicating artery aneurysms as was a hematoma in the pericallosal cistern with pericallosal artery aneurysms

Repeat CT examinations were performed in 22 patients and cerebral angiography in 20 of them on the same day as the repeat CT scanning Vascular spasm was present at 16 angiographic examinations In 10 of these patients no clinical indication of brain ischemia existed and CT scanning did not disclose infarction In the remaining 6 patients a deterioration of the clinical condition was recorded and in 5 of them the CT scan had changed to abnormal either indicating infarction (3 cases) or newly formed hematomas (2 cases) In 3 patients without spasm at angiography or a deterioration of the clinical condition the CT scan was without abnormality One patient had no spasm at angiography but clinical signs of brain ischemia CT scanning revealed a newly formed hematoma No repeat angiography was performed in 2 patients in both the clinical condition deteriorated and in both CT findings indicated edema or infarction

Discussion

In 33 of 44 patients (75 %) examined by CT within 5 days of the bleeding episode blood could be recorded in the subarachnoid cisterns The number of

Table 4

Distribution of cisternal blood in 31 patients with either a single aneurysm or identified ruptured aneurysm

	Inter hemi spheri fissure	Sylvian fissure bilat	Sylvian fissure unilat	Supra sellar cistern	Ambient cistern	Pontine cistern	Ponto-cere bellar cistern	Pericallosal cistern
Middle cerebral artery	4/8	6/8	1/8	4/8	3/8	–	–	1/8
Anterior communicating artery	10/10	1/10	3/10	4/10	3/10	–	–	–
Posterior communicating artery	3/8	/8	5/8	7/8	6/8	1/8	1/8	–
Pericallosal artery	?/	–	1/	1/	–	–	–	?/?
Posterior inferior cerebellar artery	–	–	–	1/1	1/1	1/1	–	–
Anterior inferior cerebellar artery	–	–	–	1/1	1/1	–	1/1	–

patients with altered attenuation values in the cisterns was certainly higher as only those cases where the attenuation values were distinctly above the values of the brain tissue were defined as blood in the cisterns If the CT scanning was performed within 2 days 27/32 patients (81%) had blood in the cisterns No blood was found in 5 patients with the following location of the aneurysm one on anterior communicating one on posterior communicating artery one on posterior inferior cerebellar and 2 on pericallosal artery In 6 further patients examined within 5 days without blood in the cisterns the aneurysm location was one on middle cerebral 3 on posterior communicating and 2 on posterior inferior cerebellar artery

These results are in accordance with those reported by KENDALL et coll and confirm the high accuracy of CT scanning in the detection of subarachnoid hemorrhage

The lowering of the cisternal attenuation values after the elapse of 5 days is probably due to the disintegration of the hemoglobin molecule it coincides in time with the appearance of vascular spasm

No strict correlation was found between the distribution of blood in the cisterns and the site of the ruptured aneurysms although some features are discernible In rupture of an anterior communicating aneurysm blood is commonly found in the suprasellar cisterns both Sylvian fissures as well as in the interhemispheric fissure with a small localized hematoma in the cisterna lamina terminalis (Fig 3) A flat hematoma in the pericallosal cistern may be found with rupture of a pericallosal artery aneurysm Presence of blood in one Sylvian fissure or a preponderance of one side sometimes with a localized small or large hematoma in the Sylvian fissure occurred with middle cerebral artery aneurysms Blood in the pontine or ponto cerebellar cisterns only occurred with a posterior fossa localization indicating vertebral angiography as the first angiographic procedure The distribution of blood in the ventricle has not been analysed in detail Apparently blood can be present in the fourth ventricle without being detectable in the lateral ventricles in rupture of a supratentorial aneurysm probably because of a retrograde circulation of the cerebrospinal fluid The distribution of blood is not only depending upon the localization and direction of the aneurysm but probably also upon the position of the head during the bleeding episode (HAYAKAWA & WALTZ 1978)

An analysis of these appearances together with the existence of a hematoma will usually be sufficient to decide the vessel to approach primarily at angiography Large hematomas in the basal gangli[a] with or without blood in the Sylvian fissure can be found with middle cerebral artery aneurysm and i[n] such cases an angiography is necessary for exclusion of such an aneurysm when there is no evidenc[e] of blood in the cisterns

The unique potential of CT to detect patholog[ic] alteration of the brain substance makes it possible t[o] record not only intracerebral hematomas but als[o] regions with edema or necrotic brain tissue Th[e] vascular spasm occurring as a secondary phenomenon in subarachnoid hemorrhage 3 days or later afte[r] the bleeding episode is still of questionable signifi[-] cance as it may be angiographically evident withou[t] any clinical signs of brain ischemia On the othe[r] hand a high degree of vascular spasm is a regularl[y] accompanying phenomenon to ischemia of the brai[n] or a manifest infarction During the period of angio[-] graphically demonstrated vascular spasm onl[y] those patients with clinical signs of ischemia had CT findings indicating an infarction or (in one case) a new intracerebral hematoma

Conclusions

CT scanning is a useful and reliable method to identify a subarachnoid bleeding provided the examination is performed within 2 days of the bleeding The distribution of cisternal blood can be iden[-] tified which in combination with the localization o[f] a possible intracerebral hematoma yields a rathe[r] good predictability as to the site of the rupture[d] aneurysm even when multiple aneurysms are pres[-] ent Thus the subsequent angiography can be di[-] rected to the relevant vessel in most cases simplify[-] ing the identification of the ruptured aneurysm

Repeat examination demonstrates a good correla[-] tion between CT findings and the existence of a clinically important ischemic lesion due to arteria[l] spasm Angiographic spasm seems to be of no sig[-] nificance if not associated with clinical signs on CT a repeat bleeding can be differentiated from an in[-] farction

CT should be the first diagnostic procedure fol[-] lowed by angiography Repeat angiography can be replaced by repeat CT for examination of patien[ts] with deterioration of the clinical condition

SUMMARY

Repeat CT scanning and cerebral angiography has been performed in 68 consecutive patients with subarachnoid hemorrhage Blood in the subarachnoid cisterns could be discerned in 27 of 32 patients provided the examination was performed within 2 days of the bleeding The distribution of cisternal blood can be identified which in combination with the localization of a possible intracerebral hematoma yields a rather good predictability as to the site of the ruptured aneurysm The subsequent angiography can thus be directed to the relevant vessel in most cases Repeat CT scanning can replace angiography in the evaluation of patients with deterioration of the clinical condition

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EPIDUROGRAPHY WITH METRIZAMIDE IN RHESUS MONKEYS

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W C SCHOENE and P FOURNIER

Epidurography a procedure that can demonstrate protruded intervertebral discs concealed within the epidural space has not been widely accepted be cause ionic water soluble contrast media are toxic in the subarachnoid space where they are capable of causing hypotension convulsions and even death (NOZRKI 1964 LUYENDIJK & VAN VOORTHUISEN 1966 NAGAMINE 1970) However epidurography with metrizamide (Amipaque Nyegaard Oslo Nor way) a non ionic water soluble contrast medium appears to be safe since it is relatively non toxic in the subarachnoid space (GONSETTE 1973 SKALPE et coll 1973 HAUGHTON et coll 1977)

Materials and Methods

The series consisted of 12 adult Rhesus monkeys (Macaca mulatta) equally divided into 3 groups In each group of 4 monkeys epidurography with met rizamide was performed in 3 monkeys and an epidural injection of physiologic saline was per formed on the fourth monkey who acted as a con trol Before the injection of contrast medium the monkeys were anesthetized with intramuscular ketamine hydrochloride (10 mg/kg) and booster doses were given every 20 to 30 min The lumbar and sacral regions were shaved and cleaned

In Group I one epidurography was performed in each monkey with a No 17 gauge needle (1 50 mm) fluoroscopically directed through the sacral hiatus with the monkey in the prone position Advance ment of the needle to the S1 S2 interspace was per formed after the monkey had been turned laterally 3 to 5 ml of metrizamide was injected into the epidural space at concentrations of 200 or 280 mg I/ml and in the control monkey 5 ml of saline CT scans of the lumbosacral region were performed on one monkey following epidurography

In Group II 2 epidurographies were performed in each monkey the first in a manner similar to the one in Group I in the second a catheter was used The catheter was advanced through the needle to the L7 S1 interspace after the needle had been intro duced through the sacral hiatus Three to 5 ml of metrizamide (280 mg I/ml) was injected and in the control monkey 5 ml of saline CT scans of the lumbosacral region were performed on 2 monkeys

In Group III a lumbar myelography was per formed immediately followed by epidurography The myelography was carried out by fluoroscopical ly advancing a No 22 gauge needle (0 72 mm) be tween the L7 S1 spinous processes and injecting 1 to 2 ml of metrizamide 200 or 280 mg I/ml into the subarachnoid space The epidurography was per formed immediately after the myeolography by either advancing the needle into the anterior epi dural space or repositioning it laterally where an additional 3 ml was injected In the control monkey 3 ml of saline was injected into the subarachnoid and epidural spaces CT scans of the lumbosacral region were performed on one monkey

In all groups the position and extension of the contrast medium was recorded by radiography All

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Table

Review of the epidurographies performed with metrizamide

Injection technique	Concentration (mg I/ml)	Volume (ml)	No of examinations	Difficulty during puncture	Quality of examination	Interval between last epidurography and killing (days)	Microscopy
Epidurography							
Group I Needle	200	5	1	+	Good	30	Normal
	280	3	1	+	Good	3	Infection
	280	5	1	0	Good	7	Normal
	Saline	5	1	0	–	3	Normal
Group II Catheter	280	–	2	+	Good	20	Degeneration
	280	3–5	2	+	Good	40	Normal
	280	5–5	2	+	Good	11	Normal
	Saline	5–5	2	0	–	20	Normal
Myelography and epidurography							
Group III	200	3/3	1	0	Poor	27	Normal
	280	1/3	1	0	Good	4	Normal
	280	2/3	1	0	Good	45	Normal
	Saline	3/3	1	+	–	0	Normal

monkeys were periodically examined for any change in behavior or physical activity The weights of the animals were recorded at the beginning and end of the investigation period The monkeys were killed at approximately 3 21 and 42 days after the last epidurography The lumbar and sacral vertebrae and accompanying femoral nerves were removed en bloc and fixed in a 15 per cent physiologically buffered formalin solution for approximately two weeks before the spinal cords with meninges and epidural tissues were removed Representative sections were made of the lumbar and sacral spinal cord and femoral nerves Specimens were embedded in paraffin and stained with hematoxylin eosin

Results

Puncture of the sacral hiatus in Groups I and II was frequently difficult (5/12) because of the relatively large needle when compared with the size of the sacral hiatus During difficult punctures the monkeys were often repositioned because needle depths could not be determined fluoroscopically with the monkeys prone and centering of the needles was equally difficult with the monkeys on their sides Subsequent needle advancement to the S1 S2 level frequently resulted in the needle tip hitting the bone It was then withdrawn slightly and redirected In [illegible] of these monkeys bleeding occurred but cerebrospinal fluid was never detected in the needle Advancement of the catheter in the epidural space to the S1 S2 level was more time-consuming because optimum catheter positioning required manipulation with guide wires

A total of 9 metrizamide epidurographies were performed in Group I and II (Table) The epidural space was well outlined with contrast medium regardless of the concentration of metrizamide The anterior portion of the epidural space was demonstrated on lateral films while the lateral portion was outlined on postero anterior and oblique films (Fig 1) Nerve root sleeves were occasionally outlined beyond the intervertebral foramina (Fig [illegible] Because of a partial injection of contrast medium into the subarachnoid space nerve roots were demonstrated in one monkey Three ml of metrizamide usually filled the epidural space to the upper thoracic region while 5 ml usually filled the entire epidural space from the sacrum to the cervico-occipital junction Films exposed approximately 10 to 15 min following injection showed a decrease in concentration of the medium the margins between the contrast medium and nerve roots being less well-defined Films exposed at the conclusion of the

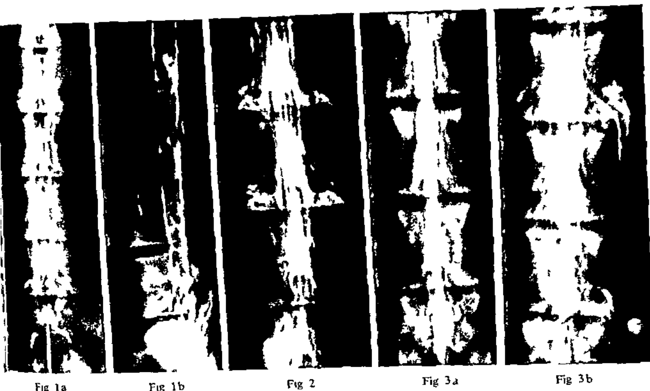


Fig 1 Metrizamide epidurography a) A p projection Lateral epidural space and the nerve root sleeves demonstrated b) Lateral projection Ventral epidural space outlined

Fig 2 Lateral recesses demonstrated Contrast medium extends through several intervertebral foramina partially outlining peripheral nerves Medium has also inadvertently entered the subarachnoid space

Fig 3 a) Myelography Subarachnoid space and nerve roots demonstrated b) Epidurography Spinal needle moved from the subarachnoid space to right lateral epidural space Contrast medium in the epidural space difficult to observe except where it has extended through the intervertebral foramina

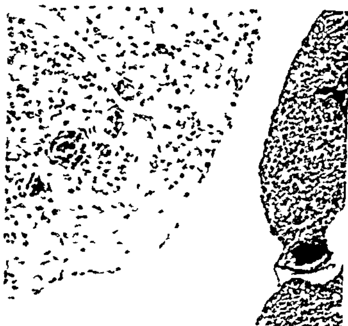
amination occasionally showed contrast medium the pelvicalyceal system

Three monkeys from Groups I and II were scanned following epidurography The scans showed that metrizamide clearly outlined the dura but the borders with the bony canal were difficult to define even with manipulation of the window width and level because of their similar attenuation (Fig) It was not possible to evaluate metrizamide and its relationship to nerve roots in either the intervertebral foramen or paravertebral soft tissue

No change in behavior or physical activity occurred in the monkeys in Group I and II However significant microscopic abnormalities were observed in 2 monkeys in which the sacral punctures had been difficult The first monkey killed 3 days after the epidurography had an acute inflammatory reaction involving the sacral dura and its adjacent epidural space This inflammation was present in the epidural fat but did not involve the epidural nerve or ganglia Occasional inflammatory cells were seen in the subdural space The wall of one blood vessel within one sacral spinal root showed acute inflammation Cultures of the epidural space were not taken because gross abnormalities were not present In the second monkey killed 3 weeks after the last epidurography the advancement of the needle had been difficult resulting in bleeding through the needle Microscopically degeneration of at least one dorsal spinal root and at least one peripheral nerve fascicle was found (Fig 4) Both axons and myelin sheaths were degenerated and associated with some macrophages These abnormalities suggested that this process was at least weeks but not months old No abnormality was found in the 2 control monkeys

The myelography in Group III did not require the monkey to be repositioned and was successful as long as the needle was maintained in the midline The epidurography was more easily performed by repositioning the needle into the lateral epidural space than by advancing it into the anterior portion of the epidural space

The myelography outlined the subarachnoid space (Fig 3a) The epidurography which followed outlined the epidural space but the contra[illegible] in the subarachnoid space distracted



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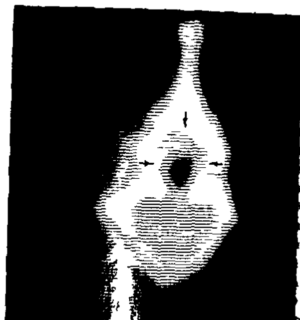


Fig 5

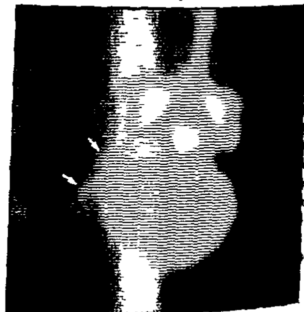


Fig 6

Fig 4 Degenerating nerve fascicle in the cauda equina Hematoxylin-eosin

Fig 5 CT scan through a lumbar vertebra Width and position of epidural space *The outer border is poorly defined* (→)

Fig 6 CT scan through a lumbar vertebra In the center of the spinal canal is a *homogeneous* high attenuating area representing subarachnoid *metrizamide* Epidural contrast medium surrounds the *subarachnoid space* Some medium extends into the paravertebral soft tissues (→)

tion of the epidural space (*Fig 3b*) CT scans were also difficult to evaluate because of contrast medium in both the subarachnoid and *epidural* space (Fig 6) No clinical or microscopic abnormalities were found in the monkeys in Group III

Discussion

Epidurography using *ionic* water soluble contrast media has proven effective in diagnosing herniated intervertebral discs The *reported* diagnostic accuracy in epidurography (90%) appears to be higher than that in subarachnoid *myelography* (YAMAMURA 1967) The reasons *for this* high accuracy are twofold (1) disk protrusions and *herniations* deform the epidural space before they *deform the* subarachnoid space thus contrast *examination of the* epidural space allows earlier and more accurate diagnosis of these lesions and (2) *correlation* between the patient s original symptoms and complaints of pain during the injection *of* contrast medium has been helpful in *diagnosing herniated* discs (LUYENDIJK & VAN VOORTHUISEN HOSH... 1966)

Metrizamide a non ionic water *soluble* contrast medium demonstrates the epidural *space* as well as ionic water soluble media but *has the* advantage of being relatively non neurotoxic *in the* subara...

pace The necessity of having a safe water soluble ubarachnoid contrast medium was evident in one monkey where medium was inadvertently injected nto both the epidural and subarachnoid space Epidurography by either ionic or non ionic contrast media causes less morbidity than myelography as ong as the subarachnoid space is not violated In act the morbidity has been sufficiently low to allow ome authors to suggest that this procedure can be erformed on an out patient basis (KETTUNEN & ALENIUS 1963 BROMAGE et coll 1978)

Metrizamide epidurography in dogs resulted in no dverse clinical reactions or injury to tissues around he epidural space which could be attributed to met izamide (KIDO et coll 1978) and the same results ere achieved in the present series of monkeys The cute inflammatory infiltrate found in the epidural pace dura and around one blood vessel in one of he spinal root fascicles is probably secondary to an nfection which occurred during a break in sterile echnique The degeneration of the dorsal spinal oot in another monkey is consistent with Wallerian egeneration of approximately 3 weeks duration It s reasonable to attribute this to trauma possibly pearing a nerve root which occurred during a dif cult needle advancement during which bleeding ccurred through the needle It seems reasonable to uggest the use of metrizamide for epidurography in umans since the procedure can detect concealed iscs and is safe if care is taken to maintain sterile onditions and the patient is monitored during the eedle manipulation

SUMMARY

Epidurography with metrizamide was performed on 9 Rhesus monkeys physiologic saline was substituted for metrizamide in 3 control monkeys Metrizamide success fully outlined the epidural space without causing any ad verse clinical effects or direct tissue injury

ACKNOWLEDGEMENT

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CISTERNAL ABNORMALITIES PRODUCED BY CLINICAL TUMOURS IN THE POSTERIOR CRANIAL FOSSA

III Tumours of the brain stem and pontine angle

M LINDQVIST

Previously cisternal distortions produced by experimental tumours in the posterior fossa (LINDQVIST & MÖLLER 1978 LINDQVIST 1978) and pneumographic cisternal distortions in a clinical series of cerebellar tumours (LINDQVIST 1980 a) and fourth ventricle tumours (LINDQVIST 1980 b) have been reported In the present report the cisternal alterations associated with tumours in the brain stem and the pontine angle are described

DAVIDOFF & EPSTEIN (1950) reported 2 cases of pontine angle tumours examined with encephalography LINDGREN (1950) emphasized the advantages of encephalography over ventriculography for the examination of the posterior fossa encephalography permitting a more comprehensive analysis of the subarachnoid cisterns both in the diagnosis of pontine angle tumours and for distinguishing tumours of the brain stem from extraaxial tumours such as chordomas of the clivus LINDGREN & DI CHIRO (1953) reported characteristics of the aqueduct and quadrigeminal cistern with different tumour locations and ROBERTSON (1957) briefly described some cisternal distortions in brain stem tumours LILIEQUIST published a detailed analysis of the normal anatomy of the subarachnoid cisterns (1959 a) as well as the pneumographic findings in tumours in the pontine angle (1959 b) He also briefly reported some cisternal abnormalities occurring in tumours of the pons (LILIEQUIST 1963) ISHERWOOD (1972) presented a pneumographic technique for demonstration of very small tumours in the pontine angle

Definitions The orientation of the structures of the posterior fossa is that given by CORRALES & GREITZ (1972) i e supero inferiorly parallel to the clivus antero posteriorly at right angles The definitions used in the present report are the same as those used previously (LINDQVIST & MOLLER LINDQVIST 1978 1980 a b) For nomenclature and a schematic survey of the normal anatomy of the cisterns see LINDQVIST (1980 a Fig 1)

Material and Methods

The material consisted of patients with tumours of the brain stem or the pontine angle examined with encephalography during the period 1969 to 1975 belonging to the same clinical material as the cerebellar and fourth ventricle tumours previously reported by LINDQVIST (1980 a b) Patients previously operated upon in the posterior fossa were excluded Cases with brain stem tumours of the quadrigeminal plate and adjacent structures were also excluded partly because the pneumographic findings in these types of tumours have been reported in detail by GREITZ (1972) and partly because information on the exact position and type of these tumours is often not available

The examination technique was the same as in the previous reports on cerebellar tumours (LINDQVIST 1980 a) and intraventricular tumours of the fourth ventricle (LINDQVIST 1980 b)

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In many cases with brain stem tumours surgical and microscopic confirmation was not available since patients with this tumour location are as a rule given radiation therapy without surgical intervention Tumours in the pons and medulla oblongata were therefore included even if no surgical confirmation existed provided that the size and position of the tumour were clearly demonstrated at the neuroradiologic examinations In a total of 21 cases were excluded 2 cases because the size and position of the tumour could not be definitely established one because the encephalography failed for technical reasons and one because the films had been lost The remaining 17 cases form the basis for the present analysis of tumours of the brain stem

Of a total of 70 cases with tumours in the pontine angle only those were included in which the type and position of the tumour was established at surgery or autopsy within 6 months from the time of the pneumography The following cases were therefore excluded 12 patients with small pontine angle tumours because they were treated with closed stereotactic radiation surgery (LEKSELL 1971) instead of open surgery 12 not operated upon for other reasons (usually old age or complicating disease) and outside the settled time interval between pneumography and surgery or autopsy The remaining 40 cases form the basis for the analysis of the pontine angle tumours

The sex and age distribution of the material appears in Figs 1 and 2 and the tumour type in Table 1

The brain stem tumours were divided into (Table 2) (a) tumours growing mainly in the medulla oblongata (or to the same extent in the medulla oblongata and the pons) and (b) tumours growing mainly in the pons

The pontine angle tumours were divided into (Table 2) (a) tumours limited to the pontocerebellar cistern (b) tumours mainly indenting the cerebellar hemisphere (c) tumours indenting both the cerebellar hemisphere and the brain stem and (d) tumours mainly indenting the brain stem

The position of each tumour was established by two experienced neuroradiologists who had access to all neuroradiologic examinations surgical and autopsy reports

The pneumographic films were reviewed analysed and recorded in the same way as in previous reports on tumours of the cerebellum and the fourth ventricle (LINDQVIST 1980a b) Thus all lateral tumours were treated as if situated on the

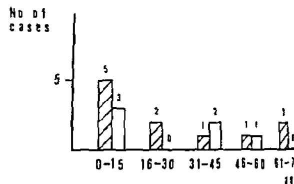


Fig 1 Sex and age distribution of 17 cases of brain stem tumour
▨ males ☐ females

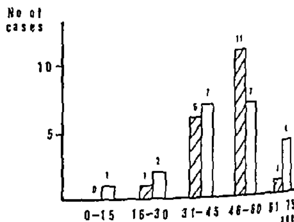


Fig 2 Sex and age distribution of 40 cases of pontine a
tumours ▨ males ☐ females

right side and all midline tumours with a tendency
lateralization were treated as if the predomina
was right sided

Results and Discussion

In Tables 3 *4 and 5* the air filling and the chara
teristic distortion of the most important cistern
structures are presented *Some cisternal featur*
that may be used to distinguish different subgroup
of brain stem and pontine angle tumours appear
Tables 6 and 7 Only cisternal structures that we
filled in at least 20 *per cent* of the cases and r
garded as *valuable for locating the tumours or d*
tinguishing them from other types of tumour in t
posterior fossa were *included*

Cisterna magna

Tonsillar herniation was present in 29 per ce
the brain stem tumours and in 45 *per cent of the po*
tine angle tumours (Table 3) *In the former tons*
herniation occurred only in tumours of the pons b
not in medulla oblongata tumours *In the latter*

Table 1

Classification of brain stem and pontine angle tumours in children and adults

Type of tumour	Children (0–15 years) No of cases	Adults (16 years or more) No of cases	Total No of cases	Total Per cent
Tumours of the brain stem				
Brain stem glioma	8	9	17	29 8
Tumours of the pontine angle				
Neurinoma	1	35	36	63 2
Meningioma	0	2	2	3 5
Cholesteatoma	0	1	1	1 8
Clivus chordoma	0	1	1	1 8
Total	9	48	57	

Microscopic confirmation not available in 11 of the cases

Table 2

Brain stem and pontine angle tumour Subgroups according to position

		No of cases
Brain stem tumours	a Tumour mainly in the medulla oblongata (or equally in the medulla oblongata and the pons)	5
	b Tumour mainly in the pons	12
Total		17
Pontine angle tumours	a Tumour limited to the cistern	4
	b Tumour mainly indenting the cerebellar hemisphere	17
	c Tumour indenting both the cerebellar hemisphere and the brain stem	15
	d Tumour mainly indenting the brain stem	4
Total		40

Table 3

Filling and distortion of the cisterna magna in tumours of the brain stem and the pontine angle All lateral tumours treated as if situated on the right side Symbols and abbreviations a=anterior p=posterior s=superior i=inferior R=right L=left 0=no change (+)=minimal change or increase +=moderate change or increase ++=marked change or increase (−)=minimal decrease −−=moderate decrease −−=marked decrease open spaces =structure not possible to evaluate

Tumour position	Brain stem Filling (%)	Brain stem Distortion	Pontine angle Filling (%)	Pontine angle Distortion
Cisterna magna				
1 Extracranial part				
lat proj	100		95	
tonsillar herniation		(+)		(+)
a p displacement of cervical medulla		p+		p(+)
2 Interhemispheric part				
lat proj	100		100	
s i diameter		–		–
3 Foramen of Magendie				
lat proj	82		72	
a p displacement		p++		p(+)
4 Vallecula axial proj	71		87	
width		+		(−)
lateral displacement		0		L+
5 Retrotonsillar spaces				
lat proj	23		30	
a p displacement		p++		p(+)
s i displacement		i++		i+
6 Cerebellomedullary fissures				
a right side axial proj	41		60	
a p displacement		p+		p(+)
lateral displacement		R(+)		L+
b left side axial proj	41		60	
a p displacement		p+		0
lateral displacement		L(+)		L+
7 Paravermian sulci axial proj	47		35	
width of inferior vermis		+		0
lateral displacement of inferior vermis		0		L+

sillar herniation was more common (50%) and more marked when the ventricular system was widened (Fig 7) than when not widened but a slight tonsillar herniation was also relatively common (32%) with normal ventricular size

The absence of tonsillar herniation in cases with tumours in the medulla oblongata is explained by the fact that the tumour displaces the tonsils posteriorly and separates them to such an extent that they can not herniate through the foramen magnum (Fig 3)

The slight degree of tonsillar herniation which is common in connection with pontine angle tumours without hydrocephalus or other signs of increased intracranial pressure may probably be explained be





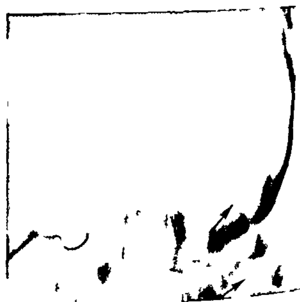


Fig 3 Tumour of the medulla oblongata a) Axial view The vallecula widened (→) the retrotonsillar spaces (⟼) between the tonsils and the inferior vermis opened up The lateral recesses (⤚) of the fourth ventricle surround the expanded medulla oblongata b) Axial tomography through the vallecula (→) The cerebellomedullary fissures (+→) separated and slightly displaced posteriorly by the expanded medulla oblongata c) Lateral midline tomography The foramen of Magendie (→) markedly displaced posteriorly by the expanded medulla oblongata Cervical medulla (⟼) displaced posteriorly below the foramen magnum

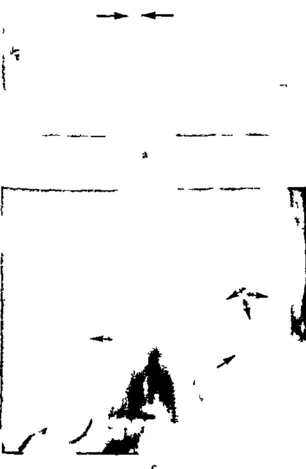
cause the tumour directly displaces the ipsilateral tonsil posteriorly and inferiorly

Posterior displacement of *the cervical medulla* below the foramen magnum was often present in the brain stem tumours especially in cases with a tumour in the medulla oblongata (Fig 3c) In the case of pontine angle tumours such a distortion occurred only when the tumour was indenting the brain stem

A moderate compression of *the interhemispheric part of the cisterna magna* against the occipital crest was observed both in brain stem and pontine angle tumours

The foramen of Magendie was markedly displaced posteriorly in cases with tumour of the brain stem In tumours of the medulla oblongata the degree of posterior displacement was as a rule the same superiorly as inferiorly (Fig 3c) while in tumours of the pons the displacement was more marked superiorly (Fig 4c Table 6) In tumours of the pontine angle posterior displacement of the foramen of Magendie occurred when the tumour was indenting the brain stem but not when it was mainly indenting the cerebellar hemisphere (Table 7)

The vallecula was markedly widened in cases with tumour of the medulla oblongata (Fig 3a b) but was of normal or only slightly increased width in pontine



b

Fig 4 Brain stem tumour with its main component in the pons a) Axial view The vallecula (→) not widened and situated in the midline b) Axial tomography through the vallecula (→) Only slight compression of the lateral recesses (↦) of the medullary cistern Cerebellomedullary fissures (>→) not displaced c) Lateral tomography The foramen of Magendie (→) displaced posteriorly particularly in its superior part The inferior vermis (↦) displaced posteriorly and slightly inferiorly The posterior part of the superior surface of the pons (↦) tilted superiorly in the interpeduncular cistern

tumours (Fig 4a b Table 6) Slight lateral displacement of the vallecula occurred in some asymmetric brain stem tumours

With tumours of the pontine angle the width of the vallecula was as a rule normal or slightly decreased when the tumour was indenting the cerebellar hemisphere but slightly increased when it was indenting the brain stem (Table 7) In most cases of pontine angle tumour the vallecula was displaced laterally which was more marked when the tumour was indenting the brain stem than when it indented the cerebellar hemisphere (Table 7)

A widening of the vallecula occurring with tumours of the medulla oblongata but not with tumours of the pons has previously been pointed out by CORRALES (1972) The vallecula was often filled in pontine angle tumours as pointed out by LILIEQUIST (1959b) He also mentioned that the posterior part of the vallecula was often more displaced than the anterior part giving it a characteristic oblique position in the axial projection This appearance was however not a constant finding in the present material being present only in 4 cases (Fig 5c)

The retrotonsillar spaces were more often filled in pontine than in medulla oblongata tumours They were as a rule markedly displaced posteriorly and inferiorly in both kinds of brain stem tumour (Fig

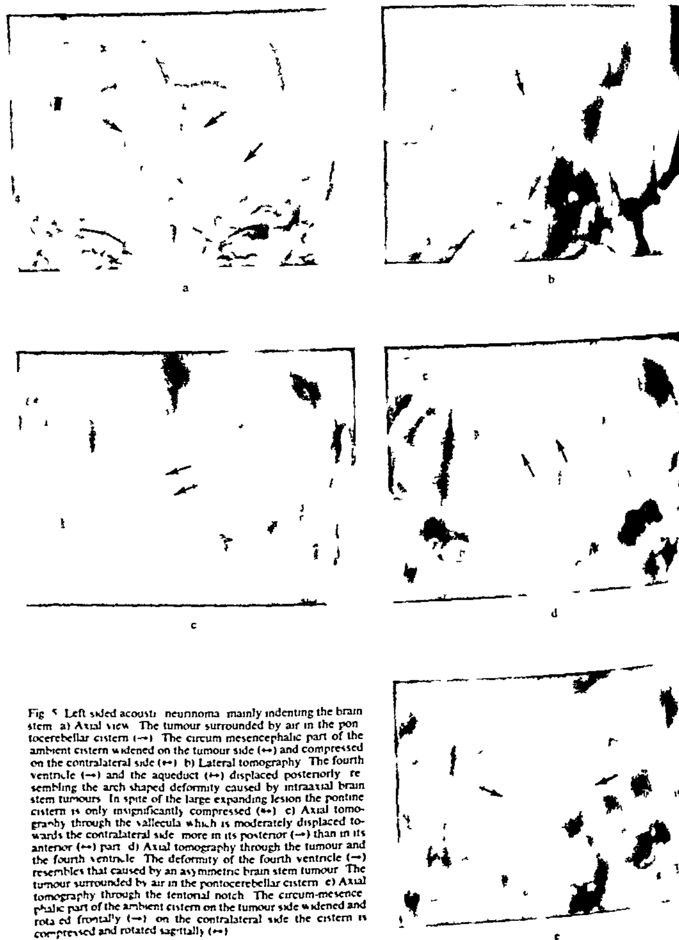


Fig 5 Left sided acousti neurinoma mainly indenting the brain stem a) Axial view The tumour surrounded by air in the pon tocerebellar cistern (→) The circum mesencephalic part of the ambient cistern widened on the tumour side (↔) and compressed on the contralateral side (↔) b) Lateral tomography The fourth ventricle (→) and the aqueduct (↔) displaced posteriorly re sembling the arch shaped deformity caused by intraaxial brain stem tumours In spite of the large expanding lesion the pontine cistern is only insignificantly compressed (↔) c) Axial tomography through the vallecula which is moderately displaced towards the contralateral side more in its posterior (→) than in its anterior (↔) part d) Axial tomography through the tumour and the fourth ventricle The deformity of the fourth ventricle (→) resembles that caused by an asymmetric brain stem tumour The tumour surrounded by air in the pontocerebellar cistern e) Axial tomography through the tentorial notch The circum-mesencephalic part of the ambient cistern on the tumour side widened and rota ed frontally (→) on the contralateral side the cistern is compressed and rotated sagittally (↔)


a


b

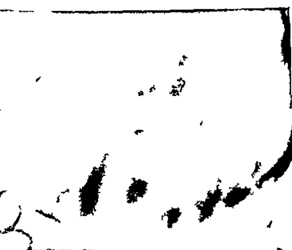

c

Fig 6 Brain stem glioma in the pons and medulla oblongata a) Encephalography lateral tomography The retrotonsillar space (→) markedly displaced posteriorly and inferiorly The pre pyramidal fissure (↦) markedly displaced posteriorly Large amount of air in the cisterna cerebelli superior which is not compressed The quadrigeminal cistern (↦) and the precentral fissure (⊸) displaced posteriorly b) Encephalography axial tomography at the level of the pontocerebellar cisterns The lateral part (→) of the pontocerebellar cisterns less compressed than the medial part (↦) c) Ventriculography lateral tomography Typical deformity of the aqueduct and the fourth ventricle

a) In cases of pontine angle tumour a moderate inferior displacement of the retrotonsillar spaces was noted but only slight posterior displacement

The cerebellomedullary fissures were separated and displaced posteriorly in the medulla oblongata tumours (Fig 3 b) while in cases with pure pontine tumours they appeared normal With pontine angle tumours the cerebellomedullary fissure on both sides was displaced towards the contralateral side The cerebellomedullary fissure on the side of the tumour was in addition somewhat displaced posteriorly if the tumour indented the brain stem but not if it indented only the cerebellar hemisphere

The paravermian sulci indicate the width of the inferior vermis A slight widening of the vermis was present in brain stem tumours as well as in pontine angle tumours indenting the brain stem In most cases of pontine angle tumour a lateral shift of the inferior vermis towards the contralateral side was also noted

The cerebellomedullary fissures indicate the border between the medulla oblongata and the tonsils An expanding lesion in the medulla oblongata will cause separation and posterior displacement of these structures The displacement of the retrotonsillar spaces in brain stem tumours is due to the fact that the tumour displaces the tonsils and the inferior vermis posteriorly and inferiorly The inferior vermis thus becomes compressed resulting in an increased width

Table 4

Filling and distortion of the medullary cistern, pontine cistern and the pontocerebellar cisterns in tumours of the brain stem and the pontine angle. Tumour positions, symbols and abbreviations as in Table 3. Additional abbreviations: Ra=right side rotated anteriorly, Rp=right side rotated posteriorly

Tumour position	Brain stem		Pontine angle	
	Filling (%)	Distortion	Filling (%)	Distortion
Medullary cistern				
1 Premedullary part				
lat proj	53		60	
a p diameter		– –		–
Lateral recesses				
right side axial proj	88		92	
a p diameter		–		+
lateral extension		–		+ +
b left side axial proj	88		90	
a p diameter				–
lateral extension				–
3 Diameter of medulla oblongata				
a p diameter lat proj		+ +		(+)
transverse diam axial proj		+ +		(–)
4 Lateral displacement of medulla oblongata axial proj		0		L+
5 Rotation of medulla medulla oblongata around axis parallel to clivus		0		Rp+
Pontine cistern lat proj	100		97	
a p diameter		– –		–
tendency of superior part of pons to recede from clivus		(+)		(+)
Pontocerebellar cisterns				
1 Right side axial proj	8		87	
width of lateral part		–		+ +
width of medial part		– –		+ +
2 Left side axial proj	76		85	
width of lateral part		–		–
width of medial part		– –		–

Medullary cistern

The premedullary part of the medullary cistern was compressed against the clivus in the cases with brain stem tumour (Table 4) as a rule more in medulla oblongata tumours than in pontine tumours (Table 6). A similar compression occurred in the pontine angle tumours most marked in tumours indenting the cerebellum (Fig 7) least in those indenting the brain stem (Fig 5b).



Fig 7 Pontine angle tumour indenting the cerebellar hemisphere. Hydrocephalus. Encephalography lateral tomograph. Tonsillar herniation (→) marked compression of the pontine cistern (↦) and of the premedullary part of the medullary cistern. Widening of the pericallosal cistern (▷→)

In the brain stem tumours both *lateral recesses* of the medullary cistern were compressed in both directions the compression being more marked in the medulla oblongata tumours than in those in the pons.

With pontine angle tumours the lateral recess was widened on the side of the tumour and compressed on the contralateral side (Fig 8).

The medulla oblongata was markedly expanded in cases with tumour of the medulla oblongata. In cases with pontine angle tumour it often appeared compressed on the tumour side in the axial projection particularly when the tumour indented the cerebellar hemisphere. In the lateral projection the medulla as a rule was of normal size but cases with an apparent expansion of the brain stem in this projection were also encountered when the tumour was indenting the brain stem. In pontine angle tumours the medulla oblongata was often rotated posteriorly on the tumour side in the axial projection and in addition displaced towards the contralateral side.

Thus brain stem tumours situated in the pons produce relatively small distortions of the medullary cistern while tumours in the medulla oblongata compress all parts of this cistern. This is logical in view of the intimate relation of the cistern to the medulla oblongata.

Pontine angle tumours displace the medulla ob

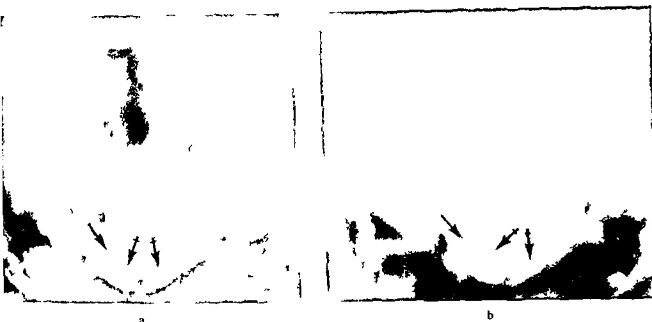


Fig 8 Right sided acoustic neurinoma mainly indenting the cerebellar hemisphere a) Axial view b) Axial tomography through the medullary cistern On the tumour side the lateral recess of the medullary cistern widened (→) and the medulla oblongata rotated posteriorly (↦)

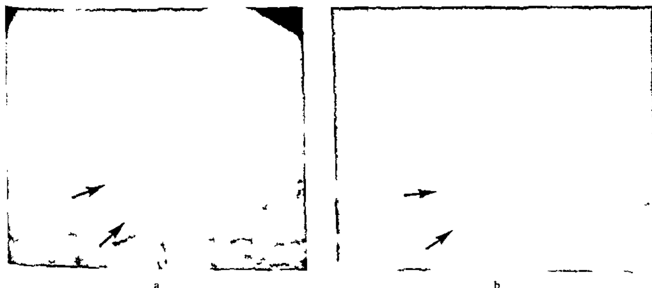


Fig 9 Right sided acoustic neurinoma mainly indenting the cerebellar hemisphere a) Axial view b) Axial tomography at the level of the pontocerebellar cisterns The brain stem (–) deformed and rotated posteriorly on the tumour side

longata towards the contralateral side and also cause posterior rotation of the medulla on the side of the tumour This causes widening of the lateral recess of the medullary cistern on the tumour side inferior to the tumour a characteristic appearance that has been described by LILIEQUIST (1959b)

Pontine cistern

The pontine cistern was markedly compressed in the a p direction in cases with brain stem tumours (Table 4) With pontine angle tumours the compression was moderate and usually more marked when the tumour indented the cerebellar hemisphere (Fig



ig 10 Tumour of the medulla oblongata. a) Axial tomography rough the pontocerebellar cisterns The lateral parts of the ontocerebellar cisterns (→) slightly compressed while the medial arts are totally compressed b) Lateral tomography The inter eduncular cistern (→) is normal Foramen of Magendie dis laced posteriorly to the same extent in its superior (↔) as in its ferior (↔) part The inferior vermis (>→) displaced posteriorly

) than when it indented the brain stem (Fig 5b Table 7)

In the pontine angle tumours deformation of the ons on the tumour side was often observed in the xial projection and at the same time the pons was omewhat rotated posteriorly on that side in some ases also slightly displaced laterally towards the ontralateral side (Fig 9)

The local deformity of the pons on the side of the umour was described by LILIEQUIST (1959 b) in the following way In the postero-anterior view it ap pears as a layer of air running along the surface of the deformed pons Behind this air layer the tumour may however penetrate more deeply into the pons The medial border of the pontine angle tumour can

Table 5

Filling and distortion of the interpeduncular cistern ambient cistern and quadrigeminal cistern in tumours of the brain stem and the pontine angle Tumour positions symbols and abbreviations as in Tables 3 and 4 Additional abbreviations fr=fron sag=sagittally i a =inferior end rotated anteriorly i p inferior end rotated posteriorly

Tumour position	Brain stem Filling ( )	Brain stem Distortion	Pontine angle Filling (%)	Pontine angle Distortion
Interpeduncular cistern				
Lat proj	100		97	
a p diameter		0		0
s i diameter		–		(–)
s i displacement of pons		s+		s(+)
s i inclination of the posterior part of the superior surface of the pons		s+		0
Ambient cistern				
Circum mesencephalic part axial proj				
a width of posterior part				
right side	71	0	75	+
left side	71	0	70	0
b width of anterior infra tentorial part				
right side	35	0	71	+
left side	35	0	49	0
c width of anterior supra tentorial part				
right side	35	–	77	+
left side	47	–	67	0
d rotation around sagittal axis perpendicular to clivus				
right side		sag(+)		fr+
left side		sag(+)		sag(+)
Quadrigeminal cistern				
1 Body of cistern lat proj	76		[illegible]	
a p displacement		p++		p( )
kinking of quadrigeminal plate		0		0
rotation of inferior end of quadrigeminal plate		ip++		p( )
2 Precentral fissure lat proj	[illegible]6		[illegible]9	
a p displacement		p++		p( )





Fig 11 Brain stem tumour with its main component in the pons Lateral tomography a) Encephalography b) Ventriculography The interpeduncular cistern (→) markedly compressed in the superior-inferior direction Marked posterior displacement of the quadrigeminal cistern (⇢) and precentral fissure (⇢) The superior cerebellar cistern (⇢) markedly compressed and the superior vermis deformed as in expanding lesion in the anterior compartment The tonsils herniated (⇢) below the foramen magnum

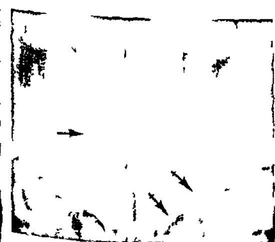




Fig 12 Right-sided pontine angle tumour indenting the cerebellar hemisphere and the brain stem a) Axial tomography at the level of the auditory canals The ambient cistern widened (→) superior to the tumour The contralateral pontocerebellar cistern (⇢) moderately compressed both laterally and medially b) Lateral tomography The widened ambient cistern superior to the tumour well demonstrated (→) The interpeduncular cistern (⇢) and the quadrigeminal cistern (⇢) are normal

...us often not be established at encephalography At ...graphy or at computer tomography these ...mours often reach surprisingly far in the medial direction

Pontocerebellar cisterns

Both in medulla oblongata and pons tumours the medial part of the pontine angle cisterns was symmetrically compressed (Table 4) The compression reached further laterally in cases with tumours of the pons (Fig 6b) than in those with the tumour limited to the medulla oblongata (Fig 10a)

With pontine angle tumours the cistern of the tumour side was markedly dilated but at the same time partly occupied by the tumour Sometimes air filling of the cistern occurred also lateral to the

Table 6

Brain stem tumours Cisternal distortions useful for differentiating tumours in the pons from those in the medulla oblongata Symbols and abbreviations as in Tables 3–5

Tumour position	Medulla oblongata	Pons
Cisterna magna		
1 Extracranial part lateral projection		
a tonsillar herniation	0	+
b a p displacement of the cervical medulla	p+	p(+)
2 Foramen of Magendie lateral projection		
a a p displacement of superior part	p++	p++
b a p displacement of inferior part	p++	p+
3 Vallecula axial projection width	++	+
4 Cerebellomedullary fissure axial projection		
a a p displacement	p++	0
b lateral displacement	+	0
Medullary cistern		
1 Premedullary part lateral projection	−−	−
2 Lateral recesses axial projection		
a a p diameter	−−	−
b lateral extension	−−	−
Pontocerebellar cisterns axial projection		
a width of medial part	−−	−−
b width of lateral part	(−)	−−
Interpeduncular cistern lateral projection		
inclination of the posterior part of the superior surface of the pons	0	s++
Quadrigeminal cistern lateral projection		
a a p displacement	0	p++
b a p rotation of inferior end	p+	p++

tumour This was most common with small tumours but was also encountered in some cases with large tumours (Fig 5a d) The contralateral pontine angle cistern was as a rule moderately compressed in cases with pontine angle tumours

The difference in width between the medial and the lateral part of the pontine angle cistern is to some extent characteristic for brain stem tumours a feature that has not been reported previously RUGGIERO (1957) as a rule found no distortions of the pontine angle cistern in cases of brain stem tumour On the other hand the typical distortions of these cisterns in pontine angle tumours are well known and LILIEQUIST (1959b) also described the compression of the contralateral pontine angle cistern

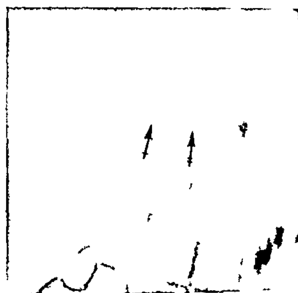


Fig 13 Tumour of the pons and the mesencephalon lat tomography Marked local widening of the quadrigeminal cist Marked posterior displacement of the quadrigeminal plate (and the precentral fissure (⟷)

Interpeduncular cistern

Neither in brain stem nor in pontine angle tumo was the a p diameter of the cistern reduced (Tal 5) On the other hand the supero inferior diame was reduced in brain stem tumours usually more tumours of the pons (Fig 11a) than in tumours the medulla oblongata (Fig 10b) The compress of the cistern in this direction was also more mark in cases with widening of the ventricular syste Moderate supero inferior compression of the cist was also encountered in cases with pontine an tumours with widening of the ventricular system

With tumours in the pons the posterior part of upper surface of the pons was tilted superiorly (F 4c) while such a distortion was not demonstrated tumours of the medulla oblongata (Fig 10b) or the pontine angle (Fig 12b) A moderate upw displacement of the pons occurred in both groups brain stem tumours on the other hand in pon angle tumours only a slight upward displacem was found

The distortion of the interpeduncular cistern thus be explained only partly by hydrocephalus w widening of the anterior part of the third ventr (LINDQVIST 1980a) Some of the abnormalities the superior displacement of the pons in brain st tumours and the superior tilt of the posterior part the upper surface of the pons in pontine tumou are probably due to direct influence on the cistern the tumour itself

Table 7

Pontine angle tumours Cisternal distortions useful for differentiating pontine angle tumours Symbols and abbreviations as in Tables 3–6

Tumour position	Tumour mainly indenting		
	Cerebellum	Cerebellum and brain stem	Brain stem
Cisterna magna			
1 Foramen of Magendie lateral projection a p displacement	0	p(+)	p+
2 Vallecula axial projection			
a width	(−)	(−)	+
b lateral displacement	+	+	++
Medullary cistern lateral projection			
width of premedullary part	−−	−	
Pontine cistern lateral projection			
width	−	(−)	0
Quadrigeminal cistern lateral projection			
a a p displacement	p(+)	p(+)	p+
b a p rotation of inferior end	p(+)	p(+)	p+

Ambient cistern

The circum mesencephalic part of the ambient cis rn was only slightly deformed in cases with brain em tumours (Table 5) With pontine tumours a ndency towards compression of the anterior supra ntorial part of the cistern and towards sagittal tation of the cistern on both sides was noted

In the case of pontine angle tumours the width of e cistern was as a rule increased on the side of the mour and normal on the contralateral side an vious rotation frontally on the tumour side and me rotation sagittally on the contralateral side was lso noted (Fig 5a e for a detailed description of ese complex rotation movements cf LINDQVIST 78 p 572) The widened ambient cistern on the mour side was sometimes also demonstrated in the eral projection (Fig 12)

The widening of the ambient cistern on the mour side in cases of pontine angle tumour was scribed by LILIEQUIST (1959 b) as a common and pical finding in this type of tumour

Quadrigeminal cistern

In the case of tumour in the medulla oblongata the stortion of the quadrigeminal cistern was slight and often consisted only of a small posterior rotation of the inferior part of the quadrigeminal plate and posterior displacement of the precentral fissure (Table 6) On the other hand pontine tumours caused marked posterior displacement of both the quadrigeminal plate and the precentral fissure (Fig 11 Table 6)

Pontine angle tumours indenting the brain stem altered the quadrigeminal cistern as with brain stem tumours (Table 7) other types of pontine angle tumour caused only slight distortion of the quadrigeminal cistern

In 2 cases with pons tumours a marked local widening of the quadrigeminal cistern was observed (Fig 13)

The typical deformity of the aqueduct and the quadrigeminal cistern associated with brain stem tumours was described by LINDGREN & DI CHIRO and by LILIEQUIST (1963)

Remaining cisterns

The crural cisterns delineate the anterior lateral part of the cerebral peduncles In 4 cases of pontine tumour the peduncles were expanded indicating extension of the tumour to the mesencephalon

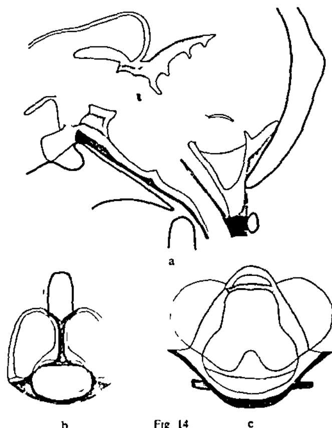


Fig 14

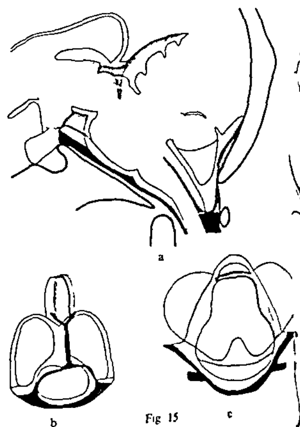


Fig 15

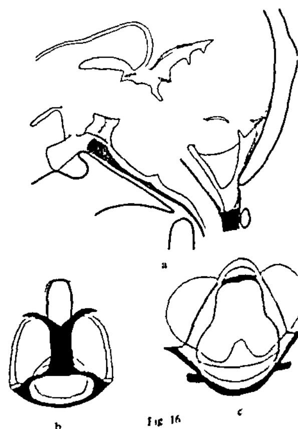


Fig 16

Fig 14 Drawings of some important cisternal deformities in tumours of the vermis a) Lateral view b) Axial view of the cisterns inferior to the fourth ventricle c) Axial view of the cisterns adjacent to the tentorial notch The normal appearance of the cisterns is indicated by means of continuous lines Cisternal structures possible to evaluate in tumour cases indicated with shaded areas (From LINDQVIST 1980 a Fig 16)

Fig 15 Drawings of some important cisternal deformities in tumours of the right cerebellar hemisphere (cf Fig 14) (From LINDQVIST 1980 a Fig 17)

Fig 16 Drawings of some important cisternal deformities in tumours from the roof of the fourth ventricle (cf Fig 14) (From LINDQVIST 1980 b Fig 8)



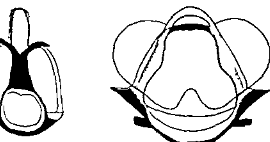
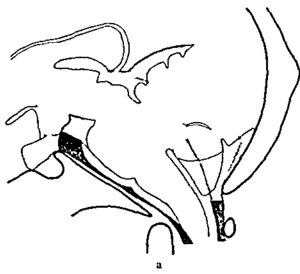


Fig 17



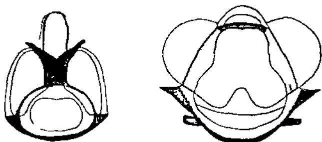
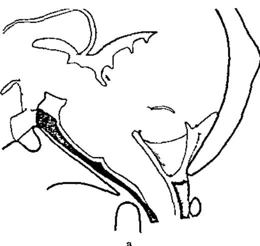


Fig 18



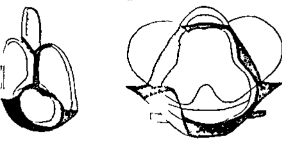


Fig 19

Fig 17 Drawings of some important cisternal deformities in tumours from the floor of the fourth ventricle (cf Fig 14) (From LINDQVIST 1980b Fig 9)

Fig 18 Drawings of some important cisternal deformities in tumours of the brain stem (cf Fig 14)

Fig 19 Drawings of some important cisternal deformities in tumours of the right pontine angle (cf Fig 14)

Typical cisternal features of brain stem tumours and pontine angle tumours

Lateral projection

Tumours of the brain stem	Tumours of the pontine angle
Tonsillar herniation with tumours of the pons but not of the medulla oblongata	Tonsillar herniation in many cases particularly in those with widening of the ventricular system
Compression of the interhemispheric part of the cisterna magna against the *occipital crest*	Compression of the interhemispheric part of the cisterna magna against the occipital crest
Posterior displacement of the foramen of Magendie	Some posterior displacement of the foramen of Magendie in cases with tumours indenting the brain stem
Marked posterior and inferior displacement of the retrotonsillar spaces	Moderate posterior and slight inferior displacement of the retrotonsillar spaces
Marked compres ion of the medullary and pontine cisterns	Moderate compression of the medullary and pontine cisterns *more marked in tumours* indenting the cerebellar hemisphere than in tumours indenting the brain stem
Moderate supero-inferior compression of the interpeduncular cistern moderate upward displacement of the pons In pontine tumour superior tilting of the posterior part of the upper surface of the pons but not in medulla oblongata tumours	Only slight supero inferior compression of the interpeduncular cistern and slight upward displacement of the pons
In cases with pontine tumours marked posterior displacement of the quadrigeminal plate and the precentral fissure as well as posterior rotation of the inferior part of the quadrigeminal plate In tumours of the medulla oblongata slight posterior rotation of the inferior part of the quadrigeminal plate and marked posterior displacement of the precentral f ssure	No or very slight distortion of the quadrigeminal cistern In tumours indenting the brain stem slight posterior rotation of the inferior part of the quadrigeminal plate and some posterior displacement of the precentral fissure may occur

Axial projection

Tumours of the brain stem	Tumours of the pontine ang
Slight widening of the inferior vermis	Contralateral di placement the inferior vermis and sl widening of the vermis particularly in cases wit tumours indenting the b stem
Width of the vallecula marked*ly increased in tumours in the* medulla oblongata normal in pontine tumours	Normal width of the valle *which is often displaced* towards the contralateral
Cerebellomedullary fissures separated and displaced posteriorly in medulla oblongata tumours unchanged in pontine tumours	Cerebellomedullary fissur both sides displaced contralaterally on the tumo side also posteriorly
Compression of the lateral recesses of the medullary cistern most marked in medulla oblongata tumours	The lateral recess of the medullary ci tern widene the tumour side com e on the contralateral side *Medulla oblongata rotate* posteriorly on the tumour side and displaced toward the contralateral side
Both pontocerebellar cisterns uniformly compressed with tumours of the pons In medulla oblongata tumours the medial part of the cisterns more compressed than the lateral part	The pontocerebellar ci ern on the tumour side marke widened and totally or pa occupied by the tumour Moderate compression of contralateral pontocerebel cistern
Very slight distortion of the circum mesencephalic parts of the ambient cistern	The circum-mesencephalic part of the ambient cistern widened on the tumour si and rotated frontally The cistern on the contralatera side rotated sag ally

In most cases of pontine angle tumour with filling of the crural cisterns no abnormality was noted but in some cases the peduncle on the tumour side was displaced posteriorly or medially This should indicate extension of the tumour into the tentorial notch which was also confirmed by the surgical report in the majority of these cases

The superior cerebellar cistern was possible to evaluate in the lateral projection in approximately half of the cases In all cases of brain stem tumour with filling of this structure the superior vermis was compressed similar to the findings in expanding lesions in the anterior compartment of the posterior fossa (Fig 11)

In cases of pontine angle tumour the shape of the superior vermis was usually normal but in some cases particularly in those with the tumour indenting the brain stem the vermis was slightly compressed as in expanding lesions in the anterior compartment

The chiasmatic cistern was filled in nearly all cases As in cases with other tumour positions in the posterior fossa (LINDQVIST 1980a b) this cistern was often compressed when hydrocephalus was present but was otherwise without distortion

The cistern of the lamina terminalis was filled in a little less than one third of the cases and was without abnormality

The pericallosal cisterns were filled in the axial projection on one or both sides in approximately 20 per cent of cases with brain stem tumours and in approximately 35 per cent of those with pontine angle tumours *the wings of the ambient cistern* were filled in approximately 30 per cent with brain stem tumour and in 60 per cent with pontine angle tumour *The cisterna veli interpositi* was filled in approximately 10 per cent in brain stem tumour and in 20 per cent in pontine angle tumour All these cisterns were often widened in cases with supratentorial ventricular dilatation (Fig 7) but otherwise without distortion In cases with unilateral filling no correlation was found between the filled side and the tumour side which is in agreement with the finding in cases with other tumour positions in the posterior cranial fossa (LINDQVIST 1980a b)

The cisternal distortions for different tumour locations in the posterior fossa based on the results reported in Parts I II and III are summarized in Figs 14 to 19 Figs 14 and 15 demonstrate the cisternal distortions in tumours of the vermis and the right cerebellar hemisphere respectively (LINDQVIST 1980a) Figs 16 and 17 those in tumours originating from the roof and floor of the fourth ventricle (LINDQVIST 1980b) and Figs 18 and 19 those in cases with tumours of the brain stem and pontine angle respectively Typical cisternal distortions associated with tumours of the brain stem and pontine angle are listed on page 354

Within the groups the cisternal features vary somewhat between different cases due to the size and position of the tumour the absence or presence of hydrocephalus etc nevertheless the cisternal distortions are usually so characteristic that the different tumour groups can be distinguished from each other

SUMMARY

The pneumographic appearances of the subarachnoid cisterns have been analysed in detail in a clinical series of 17 patients with brain stem tumours and in 40 with pontine angle tumours The cisternal distortions may be used to distinguish tumours in the pons from tumours in the medulla oblongata and also to distinguish tumours of the pontine angle with different modes of growth e g tumours mainly indenting the cerebellar hemisphere from those mainly indenting the brain stem The results should be applicable also for an analysis of cisternal pathology by other methods such as computer tomography and cisternography with positive contrast media

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IDIOPATHIC HYPERTROPHIC SUBAORTIC STENOSIS

III Analysis of the myocardial fibre shortening of the free left ventricular wall by means of geometric models

G KVAM

The unique shape of the hypertrophic muscular interventricular septum in idiopathic hypertrophic subaortic stenosis (IHSS) convex longitudinally and concave transversely towards the left ventricle (HUTCHINS & BULKLEY 1978) results in an isometric mode of contraction of the septum (Part I B KVAM 1980) Some degree of contraction of the wall around the septal attachment most probably causes the thickness of the attachment to be reduced therefore the more axial parts of the septum increase in thickness contributing to a straightening out of the transverse concavity during the contraction The outer wall at the septal attachment also increases in thickness in systole Consequently this increase in wall thickness effects a squeezing of the septum from the sides and the apical end Therefore it increases slightly in thickness contributing to the decrease in left ventricular volume

The systolic septal shortening is markedly reduced (Part I A KVAM 1980) and the septum does not bend towards the right ventricle during the systolic contraction It therefore acts as a suspender for the rest of the wall For the sake of simplicity it is here regarded as a stiff flat structure with the free wall attached around its sides and one end the free wall encroaching upon the septum during contraction The diastolic transverse section of the left ventricular cavity in IHSS may then be regarded as a half circle the diameter representing the septal wall (Part I B)

When the free (non septal) wall contracts its increase in thickness consequently causes some expulsion of the ventricular volume Therefore a thick wall does not have to shorten to the same extent as a thin wall in order to effect the expulsion of a certain amount of blood

The change in relative oblonguity of the cavity during contraction also influences the effect on the ventricular volume produced by a certain degree of myocardial fibre shortening

CATE et coll (1977) proposed that the systolic function of the left ventricle can be maintained by three different compensatory mechanisms (1) increase of dimension (Starling mechanism) (2) increase in systolic thickening and (3) increase in systolic contraction velocity

In this report other mechanisms secondary to the specific geometry as described are discussed and evaluated These mechanisms cannot be regarded as compensatory in the ordinary sense of the word They represent geometric properties of the heart itself and determine which compensatory mechanisms are possible in a given heart The compensatory mechanisms which then occur should be dependent upon the tension distribution in the ventricular wall the state of the heart muscle the function of the valvar apparatus the blood pressure and other physiologic variables

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IHSS is characterized by a high ejection fraction (EF) and an early ejection of a large fraction of the stroke volume (SV) (HERNANDEZ et coll 1964 GOTSMAN & LEWIS 1974) The specific geometric shape and mode of contraction of the left ventricle in IHSS may explain these facts The maximum velocity of the free wall myocardial fibre shortening in IHSS may be normal and the degree of the systolic fibre shortening is probably subnormal

A model has been designed for calculating the myocardial fibre shortening of the free wall in IHSS during systolic contraction Another model was designed for calculating the fibre shortening of the normally shaped left ventricular wall from cardio angiographic parameters Both models were designed with a certain degree of similarity in an attempt to keep systematic errors similar They were built up from geometrically simple structures in order to keep the arithmetic simple

The myocardial fibre shortening of the free left ventricular wall in IHSS is compared with the fibre shortening of the left ventricular wall in control patients The two models are evaluated with respect to the effect of alteration of the different input values

Materials and Methods

The material consisted of the same 4 IHSS patients as in Parts I and II (KVAM 1980) They were males age range 24 to 64 years with subaortic chambers and subaortic pressure gradients from 35 to 130 mmHg and with elevation of the left ventricular end diastolic pressures Three had a slight mitral regurgitation negligible relative to the stroke volume The heart frequency had a mean value of 83 beats per minute (range 64–95) One of these patients was later operated upon and had the diagnosis confirmed

The 10 patients in whom biplane cineangiography had been performed (Part I B) were used as controls They were aged 23 to 60 years and examined because of anginal pain but with normal coronary angiography and with normal cine left ventricular examinations The heart frequency had a mean value of 66 beats per minuts (range 55–80 SD 8 6)

The cineangiography was performed as described in Part II and the enlargement factors were determined according to the catheter grid technique

In both groups of patients an end diastolic and a subsequent end systolic frame were identified as the one with the largest and smallest ventricular area respectively before any contraction or dilatation could be observed

The end diastolic volume (EDV) was estimated from the biplane cine films A reduction method was applied for the area of the IHSS left ventricular cavities in the 60° right posterior oblique (RPO) view to compensate for the septal bulge as described (Part II) The end diastolic areas A_{RAO} and A_{RPO} were planimetrically determined and the longest ventricular axes L_{RAO} and L_{RPO} measured The width W_d was then calculated from the 30 right anterior oblique (RAO) view and the depth D_d from the 60 RPO view according to the ellipse formula $x=4A/\pi L$

The 60 RPO length is considerably shortened Therefore the 30 RAO length is used for the calculation of EDV which was calculated according to the ellipsoid formula as

$$\frac{\pi}{6} LWD$$

L equals the length W the width and D the depth after correcting for magnification

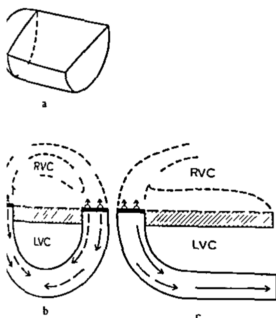
The 30° RAO frames every third frame during systole including the end-diastolic and the end systolic frames were analysed The areas A were planimetrically determined and the lengths L from the apex to the center of the aortic rings measured With a constant relationship k_1 between the width and the depth of the cavity during systole and with an enlargement factor k the ventricular volume according to the ellipsoid formula is

$$\frac{1}{k_1}\left(\frac{1}{k}\right)^3 \frac{\pi}{6} L \frac{4A}{\pi L} = k \frac{A^2}{L}$$

The relative volume k V were accordingly calculated as A /L From these relative volumes and from the known EDV the ventricular volumes were calculated for every frame analysed

The width according to the ellipse formula is 4A/ πL The relationship between the length and the width of the cavity L/W was calculated as πL²/ 4A from the end-diastolic frame in the IHSS group and from all the frames in the control group

The end-diastolic thickness t_{ed} of the free left ventricular wall was measured in the 60 RPO projection This projection was used because the outer contour of the left ventricle could not be adequately identified on the end-diastolic 30° RAO cine frames



I IHSS left ventricular model in diastole a) Perspective [drawi]ng of the model cavity A semicylinder ending in a quarter [sphe]re representing the apical part b) Transverse section of the [mode]l's semicylindrical part The model ends along the upper [horiz]ontal line c) Longitudinal section of the model LVC [left] ventricular cavity RVC Right ventricular cavity The [large]d arrows indicate lines of contraction of the free left ven[tricul]ar wall small arrows indicate counterforce from the right [side o]f the heart which is not included in the model calcula[tions] Hatched parts indicate septum

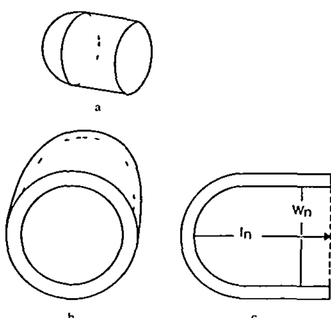


Fig 2 Normal left ventricular model a) Perspective drawing of the model cavity with its semispherical apical end and continuing as a cylinder with the other end open corresponding to the out flow end b) Transverse section of the cylindrical part of the model with a circular outline and even wall thickness The half crescent part indicates the right ventricle which is not part of the model c) Longitudinal section of normal left ventricular model l is the length and w the width of the model cavity

? of the patients with IHSS The wall thickness measured along a line at right angles to the ventricular contour from a point on the outer [conto]ur 2 cm from the intersection between the [diaph]ragm and this outer ventricular contour (2 cm [true] distance after multiplying with the enlargement [facto]r) The measured wall thickness was then [divid]ed by the enlargement factor to obtain t_{md} The [meth]od was designed to avoid measuring the apical [regio]n as it has a thinner wall than the rest of the [ventri]cle

[Fo]r each calculation of fibre shortening in the [contr]ol group the following parameters were used [as in]put in the model program (1) the end-diastolic [volu]me (2) the intermediate or end systolic volume [(3) th]e end-diastolic myocardial wall thickness t_{md} [(4)] the end-diastolic length width relationship [L_d/W]e and (5) the intermediate or end systolic [lengt]h width relationship L_s/W

[On]ly four parameters were used as input values [in th]e IHSS model The design of this model is such [that t]he relationship between the long and the trans[verse] axis of the model cavity is automatically [regula]ted directly dependent upon the other input [varia]bles during the simulated systolic contraction Therefore the fifth input parameter listed the inter mediate or end systolic length width relationship was excluded

The model representing the end-diastolic IHSS left ventricular cavity appears in Fig 1 a The trans verse section of this diastolic model cavity is a half circle It is formed as a semicylinder with one end open the other end continuing into a quarter sphere representing the ventricular apex The middle part of the left ventricular cavity is shallower than the rest because of the septal bulge The septal surface is represented in the model by a flat plane The main error in using an even height of the semicylindrical part of the model cavity is therefore primarily an error in the configuration of the model septum

The normal left ventricular cavity resembles more a full circle on transverse sections of anatomic specimens (MCALPINE 1975) The model repre senting a normal left ventricular cavity is illustrated in Fig 2 a At transverse section it appears as a circle The ventricle is formed as a cylinder with one end open representing the ventricular outflow tract The other end is closed by a semisphere re presenting the model apex

The length of the diastolic cavities in the IHSS

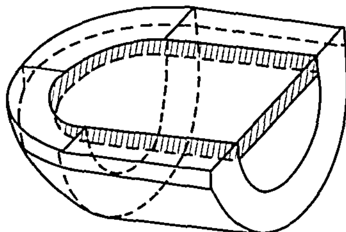


Fig 3 Perspective drawing of the IHSS left ventricular model in diastole The upper flat surface corresponds to the heavy line and its continuation in the interventricular septum in Fig 1 b and c The model septum indicated along its borders by oblique lines was given half the thickness of the rest of the ventricular wall which has a thickness equal to the measured free wall in the patient The outer shape and size of the upper plane are kept constant during the systolic contraction of the model

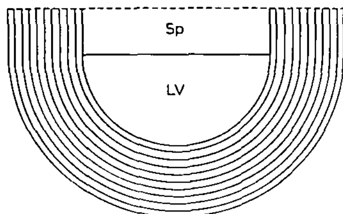


Fig 4 Transverse section of the diastolic IHSS model S Interventricular septum of the model LV Left ventricular cavity of the model The contracting wall of the model is divided into 10 concentric elements of even and identical thickness for the calculation of the diastolic volume weighted mean myocardial area A_d

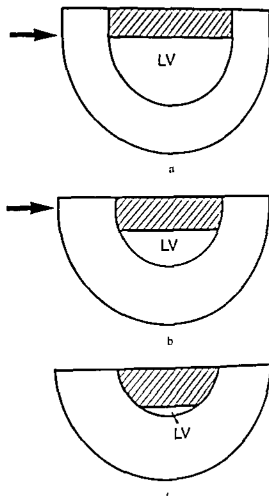


Fig 5 Transverse sections of the IHSS left ventricular m… a) Diastolic situation (corresponds to Fig 4) The arrows p… the transition between the outer semicircular part and the stra… part which borders the septum This straight part has iden… thickness to the free wall of the model b) Upon contraction… straight part above the arrows is first reduced the septal th… ness increases when the free wall thickness increases c) U… further contraction when the straight part is reduced to z… the model forms an outer and an inner circular segment The… ventricular cavity narrows increasingly because of tran… of the wall and because of increasing septal thickness LV … ventricular cavity of the model

and in the control model is equal to the length of the semicylinder/full cylinder plus the radius of the quarter sphere/half sphere respectively The width of the IHSS and the control model cavities is equal to twice the radius of the semicylinder/full cylinder respectively The radius of the quarter sphere/half sphere obviously is equal to the radius of the semicylinder/full cylinder respectively Designating this common radius r_d the length of the semicylinder/full cylinder may be expressed as $k\ r_d$

In each analysis of fibre shortening a value of k was used which made the relationship between the length and the width of the model cavity equal to the diastolic length width relationship L_d/W_d of … particular patient i e

$$\frac{(1+k_d)r_d}{2r_d} = \left(\frac{L_d}{W_d}\right) \quad k_d = \left(2\frac{L_d}{W_d}-1\right)$$

IHSS model calculations The diastolic IH… model cavity has an inner radius r_d The len… width relationship k_d of the model cavity is gi… the value L_d/W_d of the patient s left ventricle T… volume V_d of the diastolic model cavity equals

$$\frac{\pi}{3}r_d^3 + \frac{\pi}{2}r_d^2(2k_d-1)r_d$$

m V_d get the EDV value of the patient then

$$\frac{\pi r_d^3}{6}(?+3(2k_d-1))=EDV \text{ and } r_d=\sqrt[3]{\frac{6EDV}{\pi(6k_d-1)}}$$

as accordingly calculated

e diastolic IHSS model was given an even non al wall thickness t_{md} of the particular patient wall curves around the semicylinder and the ter sphere and continues up on the sides and d end of the septum of the model Both the l septum and the model wall stops abruptly in a parallel to the plane representing the septal left cular wall (Fig 1 b c) The thickness of the l septum is $k_{td}t_{md}$ and this is obviously the t of the horseshoe shaped part of the wall sur ding the septal attachment (Fig 3) k_{td} was the value 0 5

owing the inner radius r_d the wall thickness and thus also the outer radius (r_d+t_{md}) the of the semicylinder k r_d and the septal thick the outer diastolic volume of the model was lated Then the septal volume was calculated hereafter the volume of the wall myocardium e outer volume minus the volumes of the m and the cavity

free wall including the part corresponding to ptal attachment was divided into 10 concen ements with equal and even thickness (Fig 4) ach element the inner and outer surfaces and ithmetic mean between them was calculated mean surface was then multiplied by the e of the particular element The sum of the surface volume products of each element was divided by the sum of the volumes of the ele (the volume of the model outer wall) In this the volume weighted mean myocardial area in le A_d was calculated

30 cine angiography does not show any out novement of the left anterolateral heart border systole This is reflected by letting the outer plane of the model (Fig 3 uppermost remain constant in shape and dimension the simulation of the systolic contraction average increase in the overall IHSS septal ess during systolic contraction has been re from 8 5 per cent to 22 5 per cent (ROSSEN 1974 COHEN et coll 1975 CATE et coll) ompression of the septum is rather modest interposed as it is between the right and left cular walls and thus also the increase in thick f the myocardial wall around the septal attach ment This is depicted in the model by making the septum rather thin but letting the outer wall around the septal attachment have the same thickness and mode of contriction as the rest of the free wall

The catenoid like IHSS left ventricular septal sur face convex longitudinally and concave trans versely is characterized by an overall similar pres sure on either side (HUTCHINS & BULKLEY) Very small additional pressure is needed to move the wall Therefore it is reasonable to suppose that a major part of the systolic increase in septal thickness contributes to the narrowing of the left ventricle

These two aspects were reflected in the model by letting the whole increase in the septum encroach on the left ventricle but letting the septum only have half the thickness of the free wall (0 $5t_{md}$) The mus cular interventricular septum of the IHSS heart has more than 1 3 times the thickness of the free wall

Fig 5 a is a transverse section of the cylindrical part of the IHSS model in diastole The outer height of the model is the greatest distance from the upper most septal plane to the outer non septal wall mea sured along a line at right angles to the uppermost septal plane The systolic contraction is initiated by reducing the outer height This is first performed by keeping the outer shape and size of the semicylinder and quarter sphere but reducing the height of the straight part (above the arrows in Fig 5a b) Upon further contraction the straight part is reduced to zero

Thereafter the semicylinder and quarter sphere are changed into a cylindrical segment and a semi spherical cap respectively in order to simulate a contraction beyond this (Fig 5 c)

The free wall of the model bordering the cavity and the septum increases in thickness during the simulation of the systolic contraction but the thick ness of the wall remains even

The outer volume of the whole diastolic model is now known The difference between the outer dia stolic volume and the outer systolic volume is equal to the difference between the volumes of the model cavity V_d-V V_d and V being the end-diastolic and the systolic model cavity volumes respectively

The volume V_t of the septum plus the wall bordering the septum in diastole corresponding to the straight part above the arrows in Fig 5 a was calculated

If $V_d-V < V$ then the systolic model keeps an outer shape of a semicylinder plus a quarter sph plus a straight part with a height of zero or

If $V_d - V_s > V_{str}$ the systolic model obtains an outer shape of a cylindrical segment plus half a spherical cap

The further calculation depends upon this comparison of the volumes If $V_d - V_s < V_{str}$ then the following relationships prevail The volume of the straight part is reduced by a volume equal to $V_d - V_s$ The new systolic straight part therefore obtains a volume equal to $V_{str} - (V_d - V_s)$ which is the volume above the arrows in Fig 5 b This volume is divided by the area of the outer limiting plane of the model (corresponding to the uppermost plane in Fig 3) The thickness of the systolic new straight part above the arrows in Fig 5 b was thereby calculated

The volume inside the contractile wall i e the septal volume S plus the systolic cavity volume V_s has a form similar to the outer volume an inner semicylinder plus a quarter sphere both with an inner radius r and in addition the straight part which is a flat structure with a new known thickness This flat structure is formed as a semicircle with radius r_s plus a rectangle with the same length as the semicylinder kr_d and the width $2r_s$ K and r_d are known values This volume is expressed as a function of r $f(r_s) = S + V_s$ The inner radius r_s is calculated by solving $|f(r) - (S + V_s)| < 0.01$ ml using the principle of bisection (FORSYTHE et coll 1974)

In the model the ventricular surface of the septum is flat parallel to the outer septal plane during systolic contraction The systolic model cavity thereby becomes a semispherical cap continuing as a cylindrical segment Both of them have the radius r_s of the associated sphere/associated circle respectively The length of the cylindrical segment is kr_d These values are now known Therefore the volume of the systolic model cavity can be expressed as a function of the cavity height (equal to the height of the circular segment depicted on the transverse section in Fig 5 b) $V_s = g(h)$

The height of the cavity was calculated by solving $|g(h) - V_s| < 0.01$ ml

The outer systolic radius obviously equals the outer diastolic radius equal to $r_d + t_{md}$ The inner systolic radius r_s of the contractile wall known the systolic wall thickness equals $(r_d + t_{md}) - r$ The form and thickness of the free wall of the model is now known in systole As for the diastolic IHSS model (Fig 4) the free systolic wall was divided into 10 concentric elements and the volume weighted systolic mean area A was calculated

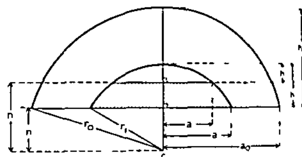


Fig 6 Transverse section of the IHSS systolic model semispherical cap/semicylindrical segment variant The same as Fig 5 c but turned upside down c Center of the associated sphere of both the outer and inner circular segment r Radius of the inner segment r Radius of the outer segment a_i Half the chord of the inner segment a_o Half the chord of the outer segment a Half the chord of the cavity segment h Height of the inner segment h_o Height of the outer segment h Height of the cavity segment n Distance from the circular center c to the outer septal plane n Distance from the circular center c to the inner septal plane i e to the septal wall of the model cavity

If $V_d - V_s > V_{str}$ the outer volume of the systolic model is smaller than the orginal outer semicylindrical/quarter spherical parts of the diastolic model The outer septal plane is constant in shape and dimension from the diastolic to the systolic model The outer systolic model is formed in this instance as a semispherical cap plus a cylindrical segment (Fig 5 c transverse section)

This transverse section is redrawn in Fig 6 upside down with the septal plane below The center of the associated circles of the outer and inner circular segments c is also drawn The outer and inner heights h and h_i and also the height of the cavity h are shown The corresponding half chords a_o, a_i and a are also shown as well as the radii r_o and r_i of the associated circles of the outer and inner circular segments

The outer volume of the systolic model V_o is equal to the muscle wall volume V_m plus the septal volume S plus the systolic cavity volume V as r is known (equal to the outer diastolic radius i e $r_d +$ t_{md}) and the length $k_d r_d$ of the cylindrical segment is also known The outer volume was now expressed by means of the formulas for the semispherical cap and cylindrical segment (Table I) by means of h $i(h_o) = V_m + S + V_s$ h was calculated by solving $|i(h_o) - (V_m + S + V)| < 0.01$ ml

The distance n from the circular center to the outer septal plane appears in Fig 6 According to Pythagoras $a_o^2 + n = r$ Obviously $h + n = r$

Accordingly $a_o + n^2 = (h_o + n)^2$ i e $n = (a_o^2$ $h^2)/2h$ h_o and a_o known n was calculated

The whole inner segment in Fig 6 has a radius r_i and a half chord a_i The distance n from the cir

Table 1

The formulas applied in the IHSS model calculations r The radius of the wall layer being calculated R_{id} The radius of the inner ventricular cavity in diastole K_d The length of the diastolic model cavity divided by its width h The height of the circular segment and semispherical cap being calculated t_s The thickness of the straight part (above the arrows in Fig 5 a and b The horseshoe shaped band is the area of active muscle bordering the septum above the arrows in fig 5 a and b corresponding to the upper straight parts on transverse section in Fig 4

Volumes	
The quarter sphere	$\frac{\pi}{3}r^3$
The semicylinder	$\frac{\pi}{2}r^2(2K_d-1)r_{id}$
The base plate	$\left[\frac{\pi}{2}r^2+(2K_d-1)r_{id}2r\right]t$
The semispherical cap	$\frac{\pi}{6}h^2(3r-h)$
The cylindrical segment	$\left[r^2\cos^{-1}\left(\frac{r-h}{r}\right)-(r-h)\sqrt{2hr-h^2}\right](2K_d-1)r_{id}$
Areas	
The quarter sphere curved part	πr^2
The semicylinder curved part	$\pi r(2K_d-1)r_d$
The horseshoe shaped band of straight part	$[\pi r+(2K_d-1)r_{id}2]t$
The semispherical cap curved part	$2\pi rh$
The cylindrical segment curved part	$2r\cos^{-1}\left(\frac{r-h}{r}\right)(2K_d-1)r_{id}$
Outer septal plane	$\frac{\pi}{2}r^2+(2K_d-1)r_{id}2r$

-ular center to the common chord is obviously identical for the inner and the outer segment According to Pythagoras $a^2+n^2=r^2$ The height of the inner segment is h_i Obviously $h_i+n=r_i$

Therefore $a^2+n^2=(h_i+n)^2$ i e $a^2=h_i^2+2h_in$ and $a=\sqrt{h_i^2+2h_in}$ n is known and a is expressed as a function of h_i The volume of the model inside the wall representing the active myocardium was now expressed by means of the volume formulas for the half spherical cap and the cylindrical segment (Table 1) with h_i as the only variable $i(h_i)=V_s+S$ as it obviously is equal to the cavity plus the septal volumes h_i was calculated by solving $|i(h_i)-(V_s+S)|<0.01$ *ml*

The model cavity is a circular segment on transverse section the cavity segment It has a common arc and thus a common center c and radius r_i with the inner segment The distance from the cavity segment to the circular center c is n_n h as well as n are now known $h_i+n=r_i$

The height h_n of the cavity segment plus the distance n_n also equals r_i Therefore $h_n+n_n=h_i+n$ i e $n_n=(h_i+n-h_n)$ a_n is half the chord of the cavity segment According to Pythagoras $n_n^2+a_n^2=r_i^2=(n+h_i)^2$ i e $a_n^2=(n+h_i)^2-n_n^2$

Substituting the expression above for n_n in this last equation $a_n^2=(n+h_i)^2-(h_i+n-h_n)^2$ and $a_n=\sqrt{(n+h_i)^2-(h_i+n-h_n)^2}$ are obtained

In this manner both n_n and a_n were expressed as variables of the cavity height h_n Again using the volume formulas for the semispherical cap and the cylindrical segment the systolic cavity volume was now *expressed* as an equation with only h_n as variable $i(h_n)=V_s$ The cavity height h_n was calculated by solving $|i(h_n)-V_s|<0.01$ *ml*

In this systolic model the thickness of the wall

representing the contractile myocardium obviously is the difference between the outer and inner heights $t_m = h_o - h$ t_m was calculated

The shape and thickness of this wall is now known As for the diastolic IHSS model (Fig 4) the wall was also in this case divided into 10 concentric even and equally thick walled elements Using the surface and volume formulas for the semispherical cap and the cylindrical segment the volume weighted mean systolic myocardial area A_s was calculated in principle as described for the calculation of the diastolic mean area The formulas applied appear in Table 1 (BRONSHTEIN & SEMENDYAYEV 1973)

Normal model calculations In the normal model the calculations are simpler If r_d is the internal radius of the normal model cavity in diastole and K_d the diastolic length width relationship then (Table 2)

$$\frac{2}{3}\pi r_d^3 + \pi r_d(2K_d - 1)r_d = EDV \;)\; r_d = \sqrt[3]{\frac{3EDV}{\pi(6K_d - 1)}}$$

r_d was accordingly calculated The length of the cylindrical part is $(2K_d - 1)r_d$ The model was given an even wall thickness equal to the diastolic wall thickness t_{md} of the patient analysed (Fig 2 b c) The outer diastolic radius is thus $r_d + t_{md}$ Using the formulas for the semisphere and the cylinder the outer model volume was calculated Subtracting the cavity volume V_d from this outer volume the myocardial wall volume of the model V_m was calculated

The wall of the diastolic normal model was divided into 10 concentric elements with even and equal wall thickness (Fig 4) The volume weighted mean myocardial area in diastole A_1 was then calculated as described for the IHSS model but using the appropriate formulas (Table 2)

The normal model in systole is much simpler than the IHSS systolic model The normal heart contracts more concentrically The model cavity was designed with the same shape as the diastolic model cavity a semisphere continuing in a cylinder with one end open corresponding to the outflow tract (Fig 2) The relationship between the length and the width of the model cavity was given a value identical with the measured length width relationship of the patient s left ventricle in the particular systolic phase being analysed The inner cavity radius in

Table 2

The formulas applied in the normal model calculations r The radius of the wall layer being calculated r The radius of the inner ventricular cavity K The length of the model cavity divided by its width

Volumes	
The semisphere	$\frac{2}{3}\pi r^3$
The cylinder	$\pi r^2(2K-1)r$
Areas	
The semisphere	πr^2
The cylinder	$\pi r(2K-1)r$

systole is r_s The cylindrical part in systole wa accordingly given a length

$$r\left(2\frac{Ls}{Ws} - 1\right)$$

L_s and W_s are the length and the width of the pa tient s left ventricle in the actual systolic phase This is exactly parallel to the normal diastolic model

V_s is the volume of the systolic model cavity anc $Ls/Ws = K$ Then

$$r = \sqrt[3]{\frac{3Vs}{\pi(6Ks - 1)}}$$

r_s the internal radius of the systolic model cavity was accordingly calculated

The systolic wall thickness t_m of the model i even The outer radius of the systolic model ac cordingly equals $r + t_m$ The outer volume equals V plus the muscle volume V_m which is known from the diastolic model The outer volume was ex pressed with the outer systolic radius as the onl variable $f(r_{so}) = V_s + V_m$ r_{so} was calculated by solv ing $|f(r_{so}) - (V_s + V_m)| < 0\,01$ ml

The systolic wall thickness t_m was then calculated as the difference between the outer and the inne radius

Thereafter as described for the diastolic model the wall was divided into 10 concentric eleme t (Fig 4) and the volume weighted mean sys li area A was calculated

Irrespective of whether a heart from the contr group was analysed by means of the normal hea model or a heart with IHSS was analysed by mean of the IHSS heart model the left ventricular fibr shortening was calculated according to the sam formula A_d is the volume weighted mean area of the

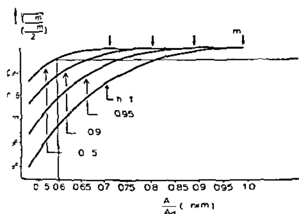


Fig 7 Graphical drawing of calculations showing the error of using the square root of the product of the systolic average length and width expressed as fraction of the corresponding diastolic values instead of the arithmetic mean value of the systolic length and width expressed in the same manner in the calculation of average systolic fibre length A Volume weighted mean myocardial area of the model in systole A_d Volume weighted mean myocardial area of the model in diastole n Average systolic length expressed as a fraction of corresponding diastolic length m Average systolic width expressed as a fraction of corresponding diastolic width The expression $\sqrt{nm}$ exactly substitutes the expression $(n+m)/2$ in the calculation of average systolic fibre length and thus in the calculation of systolic fibre shortening only when n=m (upper arrows)

wall representing the actively contracting myocardium in diastole A is the corresponding volume weighted mean area in the particular phase of the systole being analysed The myocardial fibre shortening (in per cent) was calculated according to the formula

$$\left(1-\sqrt{\frac{As}{Ad}}\right)100$$

According to anatomic drawings the myocardial wall is layered and the fibres are oriented in definite directions depending on layer and location (SOBOTTA & BECHER 1957 KATZ 1977) However it is very difficult to recognize these different layers in macroscopic sections of the heart (MCALPINE 1975) No functional difference exists between the different parts of the contractile left ventricular wall as it behaves quite as a single muscle

The area reduction and the consequent increase in wall thickness are both reflected in the systolic reduction of the mean area of the myocardial wall It is the area reduction which effects the reduction of the cavity volume The mean area reduction could be used directly as an estimate of the systolic contraction

In a geometric sense the mean fibre shortening may be defined by relating it directly to the lengthwise and crosswise shortening of the mean area

The mean diastolic area A_d may be reduced to a rectangle with the same area and with the length a and the width b The mean systolic area may correspondingly be reduced to a rectangle with the area A_s with the length na and the width mb

The average lengthwise shortening of the myocardial wall is less marked than the average transverse shortening and therefore m<n The wall shortens both lengthwise and crosswise therefore both n and m are smaller than unity

The length of any fibre which runs obliquely will during myocardial contraction shorten in an oblique direction This shortening may be described by vector principles as occurring partly lengthwise partly crosswise It may be regarded as contributing both to the overall lengthwise shortening and the overall crosswise shortening and the overall shortening in these two directions is described by the factors n and m

The systolic fibre shortening in the longitudinal direction expressed as fraction of the corresponding diastolic fibre length equals na/a=n The systolic fibre length in the transverse direction expressed as fraction of the corresponding diastolic fibre length equals mb/b=m

The overall fibre shortening may be defined as the arithmetic mean of the lengthwise and the crosswise shortening The fibre shortening expressed as a fraction of the diastolic fibre length thus equals

$$\frac{(1-n)+(1-m)}{2}=\left(1-\frac{n+m}{2}\right)$$

Expressed in per cent of the diastolic fibre length this equals

$$\left(1-\frac{n+m}{2}\right)100$$

The expression actually used to calculate the fibre shortening was

$$\left(1-\sqrt{\frac{As}{Ad}}\right)100 \text{ per cent}$$

According to the statements mentioned A = namb and A_d=ab Therefore

$$\sqrt{\frac{As}{Ad}}=\sqrt{\frac{namb}{ab}}=\sqrt{nm}$$

In Fig 7 $\sqrt{nm}/(n+m)/2$ is shown for the different values of n at different values of As/Ad The actual values for the systolic areas were from 0 57A_d and upwards in the control group and from 0 79A_d up wards in the IHSS group

In the model calculation the systolic length of the long axis in a wall layer approximately cor responding to the mean area expressed as a fraction of the corresponding diastolic length had a smaller value than 0 9 in the end of systole in the control group In the IHSS group this value was larger than in the control group

Fig 7 shows that the effect of using the term $\sqrt{nm}(=\sqrt{As/Ad})$ instead of $(n+m)/2$ gives an under estimation of the systolic fibre length as a fraction of the diastolic fibre shortening By the end of systole the calculated fibre shortening in the control group had an average value of 19 1 per cent and the overestimation in terms of fibre shortening was less than 1 25 per cent

In the IHSS group the calculated fibre shortening by the end of systole had an average value of 9 8 per cent and the overestimation in this group was then less than 0 6 per cent in terms of fibre shorten ing

In the early half of systole the overestimation for both groups is smaller than this but actually a little higher in the IHSS group than in the control group This is because in this phase of systole the calculated area reduction is similar in the two groups but n has a higher value in the IHSS group

$\sqrt{nm}$ equals $(n+m)/2$ only when $n=m$ i e when the lengthwise and the crosswise shortening ex pressed as fractions of the diastolic values are equal However the overestimation caused by using the one term for the other does not interfere with the general arguments presented in the following

The calculations were performed on a Texas Instruments programmable pocket calculator TI 59 equipped with a thermic writer PC 100B

Results

The cardioangiographic data which were used as input variables in the model evaluation of the fibre shortening for the two groups of patients appear in Table 3 as mean values ranges and standard devia tions According to the description of the models only the distolic length width relationship was used as input value in the IHSS model In the normal model the specific length width relationship of the particular systolic situation being analysed was als used as input value For this reason there is a empty space in Table 3 for the IHSS group

The average end-diastolic volumes are smaller i the IHSS group (the chance that the diastoli volumes come from the same population is less tha 5 per cent assuming normal distribution i e $p<0.05$) The mid systolic volume is clearly small in the IHSS patient group ($p<0.005$) The end systolic volume is also smaller in the IHSS grou ($p<0.01$) The ejection fraction is clearly larger i the IHSS group ($p<0.001$) The end-diastolic lengt width relationship is definitely larger in the IHS group ($p<0.0005$) and the diastolic free wall thicker ($p<0.0005$)

In Fig 8 the average length width relation ship through the systolic period is shown for th

Table 3

Left ventricular cardioangiographic data from the IHSS a control groups of patients presented as mean values ran e o values and standard deviation (Rather many decimals i clude indicates that the values are intermediate results)

Left ventricular parameters	IHSS group	Control group
End-distolic volume	116 0 ml	157 9 ml
Range	103–130	87 189
SD	11 1	29 6
Mid systolic volume	43 7 ml	101 2 ml
Range	42–49	61 1[illegible]
SD	3 7	0 7
End systolic volume	17 3 ml	46 7 ml
Range	14–23	[illegible]-64
SD	4 0	13 7
Systolic ejection fraction	0 85	0 [illegible]0[illegible]
Range	0 82–0 88	0 63-0 79
SD	0 0 4	0 054
Ventricular length/ width relationship (L/W)		
End diastole	2 78	1 60
Range	1 99– [illegible]4	1 45– [illegible]0[illegible]
SD	0 [illegible]	0 17
Mid systole		1 86
Range		1 57 [illegible]40
SD		0 [illegible]3
End systole		2 1
Range		1 6 [illegible]6
Diastolic muscle thickness	2 06 cm	0 91 cm
Range	1 79 2 37	0 64 1 11
SD	0 24	0 16

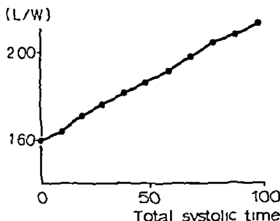


Fig 8 Left ventricular length divided by the calculated width (L/W) for the control group average values interpolated at every 10 per cent systolic time interval

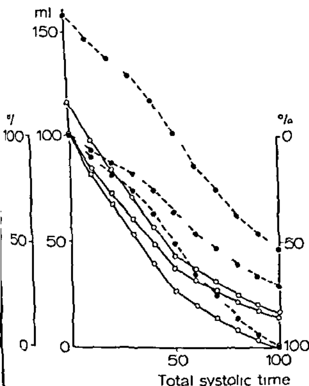


Fig 9 Left ventricular volumes interpolated at every 10 per cent systolic time interval presented in 3 different ways for the 2 groups of patients IHSS group (O) Control group (●) Upper curve in each group Left ventricular volume in ml (inner left hand scale) Middle curve in each group Left ventricular volume as per cent of EDV (outer left hand scale) Lower curve in each group Percentage of stroke volume which has been ejected (right hand scale)

control group at every 10 per cent systolic interval The width decreases relatively more than the length

In Fig 9 the average ventricular volumes at every 10 per cent systolic interval are given in three different ways for the two groups of patients In each group the upper curve represents the ventricular volume in ml (inner left hand scale) the middle curve the left ventricular volume in percentage of LDV (outer left hand scale) the lower curve the percentage of the stroke volume ejected (right hand scale) The figure illustrates lower ventricular volumes higher EF and faster ejection of the stroke volume in the IHSS group

The left ventricular data from the IHSS and the control group (Table 1) were used as input parameters in the model calculation of fibre shortening

At mid systole the calculated fibre shortening among the IHSS patients had an average value of 7 1 per cent (range 5 7–8 5 SD 1 2) in the control group 8 1 per cent (range 4 7–11 5 SD 1 9) This difference is not significant

At the end of systole the calculated average shortening among the IHSS patients had an average value of 9 8 per cent (range 8 8–11 4 SD 1 1) in the control group 19 1 per cent (range 15 7–24 7 SD 3 0) This difference is highly significant ($p < 0\ 0005$)

The mean patient values for every 10 per cent systolic time interval were used as input parameters in the models In Fig 10 the fibre shortening is plotted together with the fraction of the stroke volume ejected at every systolic time interval for both groups The calculated fibre shortening is similar for the two groups during the first half of systole thereafter the fibre shortening lags more and more behind in the IHSS group A certain degree of fibre shortening causes the ejection of a larger fraction of the stroke volume in the IHSS group than among the controls

The height of the IHSS model cavity averaged 1 60 cm at half systolic time and 0 77 cm at the end of systole The height of the normal model cavity (the diameter) averaged 4 23 cm at half systolic time and 3 13 cm at the end of systole From the model analysis using the mean patient values as input the cavity heights of the two models at every ten per cent systolic time interval appear in Fig 11 The rapidly decreasing height of the IHSS model cavity illustrates the slit like form of the cavity towards the end of systole

The influence on the calculated fibre shortening of the different input parameters was examined They

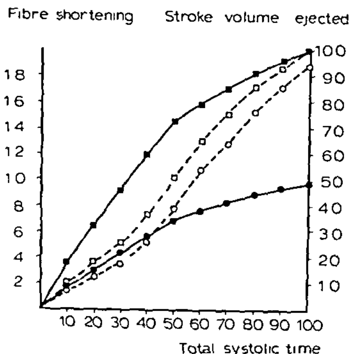


Fig 10 Per cent fibre shortening (left hand scale) and percentage of the stroke volume ejected (right hand scale) for the 2 groups of patients using mean values as input values in the model calculations Systolic period expressed as percentage of the full systolic period elapsed along the abscissa Average fibre shortening is similar for the 2 groups of patients during the first half of the systole From then on fibre shortening lags more and more behind in the IHSS group Fibre shortening in the IHSS group (●) and the control group (O) Stroke volume ejection in the IHSS group (■) and in the control group (□)

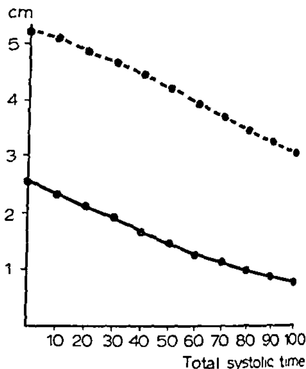


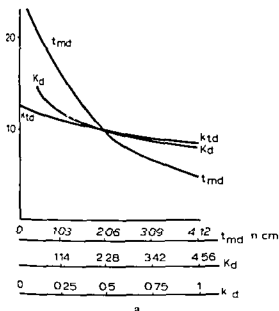
Fig 11 Calculated height of the IHSS model cavity (—) and calculated diameter of the control model cavity ( ) along the systolic period Average patient values from each group were used as input parameters

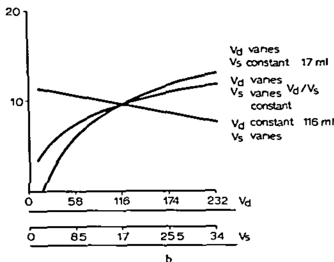
were varied one at a time keeping the others constant at average patient values V_d and V_s were also varied in parallel keeping the same relationship between them as between the average EDV and ESV

In the control model the diastolic and systolic length width relationships were also varied in parallel The relative magnitude of the two was then for each calculation kept constant as between the average end-diastolic and end systolic length width relationship

The influence of the different input parameters on the IHSS model calculation of fibre shortening appears in Fig 12 Increasing the muscle thickness increasing the length width relationship of the diastolic left ventricular cavity or increasing the left ventricular part of the septum relative to the free wall thickness all decreased the calculated mean fibre shortening which was necessary to perform the average volume reduction from end-diastole to end systole in the IHSS group (Fig 12 a) Obviously to reduce the end systolic volume the contractile wall must contract more and to effect volume reduction from a large end-diastolic volume to a fixed end systolic volume the wall must also contract more Increasing the end systolic and the end-diastolic volume together the systolic ejection fraction staying constant also demands more mean fibre shortening but not to the same degree as when only the end-diastolic volume is larger (Fig 12 b)

The corresponding influence of the input parameters in the normal model estimates of the fibre shortening is shown in Fig 13 When the end diastolic volume increases or the end systolic volume decreases the estimation of fibre shortening as expected increases When both the end-diastolic and the end systolic volume increases but V_s/V_d remains constant actually meaning that the ejection fraction remains constant the estimate of fibre shortening changes very little only increasing from 19 to 20 5 per cent when the diastolic volume increases from 100 to 300 ml (Fig 13 a) With increasing myocardial thickness the necessary fibre shortening to perform the cavity volume reduction from the standard V_d to the standard V_s is reduced The opposite is also true With decreasing myo-





1? Input parameters in the IHSS model varied systemati ' Average patient values are used for all parameters not :d (end systolic values are used) Effect on calculated fibre tening shown a) Effect of varying diastolic free wall thick t_{md} and relative thickness k_{td} of the model septum (actual diastolic thickness of the model septum $k_d t_{md}$) Influence of varying the diastolic length width relationship k_d of the model cavity also shown b) Effect of varying end diastolic volume V_d alone and together with end systolic volume V relationship between them kept constant Effect of varying V alone also shown

dial thickness the mean fibre shortening nec ary to effect this volume reduction is increased g 13 b)

f a normal ventricle with diastolic volume '9 ml and with average length width relationship l muscle thickness dilates to a new end-diastolic ume of 300 ml keeping its length width relation p then according to the model the end-diastolic ocardial wall thickness is reduced from 0 91 cm 0 65 cm This heart must perform 18 9 per cent an left ventricular fibre shortening to obtain an ction fraction of 0 704 when the end-diastolic lume is 157 9 ml but 22 9 per cent mean fibre ortening to reach the same systolic ejection frac on when the end-diastolic volume is 300 ml

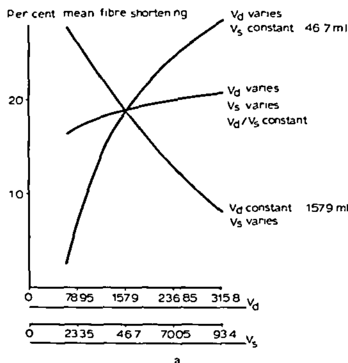
The curves in Figs 12 and 13 are extended into iprobable regions of the values for the different put parameters Within reasonable limits of these arameters the calculated and systolic fibre shorten ig of the IHSS model is always much less than the bre shortening of the normal model at the end of ystole

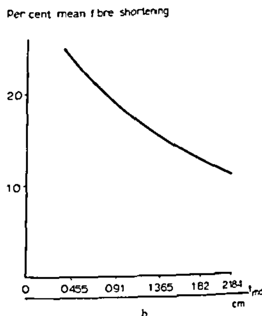
Discussion

The smaller EDV in the IHSS group has been discussed in Part II

As long as the ejection fraction and therefore the relationship between V_d and V_s of the model is constant the estimation of fibre shortening is not much dependent upon a very exact measurement of the EDV used as input V_d of the model This is apparent from Figs 12 b and 13 a The relationship between V_d and V used as input variables is independent of the exact value of V_d because V_s was calculated from the measured V_d by using the relative volumes through the systolic period

The measured wall thickness in the control group is somewhat smaller on the average than reported by DODGE (1971) for normal patients measured on the lateral wall The wall thickness in the control group was also measured by a planimetric method *(RACKLEY et coll 1964) from the 30 RAO view and* corrected for magnification The average value was then 0 985 cm (range 0 80–1 23 SD 0 16) in the control group These values were also used as input instead of the muscle thickness as measured in the 60 RPO view At 50 per cent systolic time the calculated shortening had a mean value of 7 8 per cent (range 4 9–9 9 SD 1 3) and at the end of systole the calculated shortening was 18 5 per cent (range 16 1–20 9 SD 1 5) The latter mean values do not differ significantly from the mean values calculated





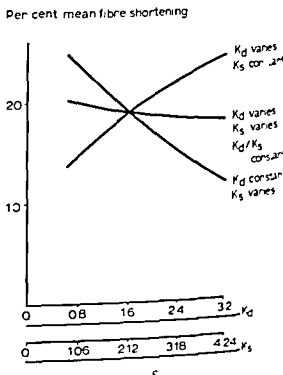


Fig 13 Input parameters in the control model varied systematically Average patient input values are used for all parameters not varied (end systolic values are used) Effect on calculated fibre shortening shown a) End-diastolic volume and end systolic volume varied alone and together In the latter case the relationship between them and thus the ejection fraction kept constant b) Diastolic wall thickness varied c) Diastolic length width relationship K_d varied alone and together with the corresponding end systolic value K Relationship between the 2 (K /K) kept constant K also varied al ne

when the myocardial wall thickness as measured on the 60° RPO film was used (8 1 and 19 1 per cent respectively)

The pulse frequency was different in the two groups ($p<0.01$) The relationship which has been shown between cavity form fibre shortening and expulsion of the stroke volume is present nevertheless The calculations of the fibre shortening are strictly geometric and not influenced by the heart rate The relationships shown are present but other interrelated relationships are present as well as between heart rate stroke volume and cardiac output and between heart rate EDV ESV and the ionotropy of the heart a most complex relationship (ILEBEKK et coll 1978)

The applied geometric models are simplifications

both for the normal left ventricle and for the IHSS left ventricle but they serve to illustrate essential differences between the two

The flat diastolic left ventricular wall of the septum in the IHSS model is a geometric simplification of the catenoid like surface convex longitudinally and concave transversely Longitudinal sections of the IHSS septum show that the longitudinal convexity causes a larger bulging towards the cavity than the transverse concavity curves away from the cavity (FARRER BROWN 1977 HUTCHINS & BULKLEY) The IHSS left ventricular cavity is long relative to the width and the longitudinal curvature does not seem less marked than the transverse per length unit The design of the model septal surface as a flat plane seems an acceptable approximation of the overall bulging towards the left ventricular cavity when the transverse section is designed as half a circle

The increase in thickness of the model septum averaged about 40 per cent in the IHSS group during full systolic contraction However the model septum was only half as thick as the model free wall in diastole In the actual heart with IHSS the interventricular septum is at least 1 3 times as thick as the free wall (EPSTEIN et coll 1974 MARON et coll 1977 REDWOOD et coll 1974) The effect of the catenoid surface which has no net pressure across its wall is most probably that the greater part of the total septal thickening occurs towards the left ventricular cavity If at least 10/13 of the septal thickening occurs in this direction then a layer of the septum at least as thick as the free wall participates in the narrowing of the left ventricular cavity (1 3×10/13=1)

The increase in thickness of a septal layer at least as thick as the free wall towards the left ventricular cavity is represented in the model by a more than twice as large systolic increase in septal thickness of a septum less than half as thick The 40 per cent systolic increase in thickness of the model septum represents an overall increase in thickness of the patient interventricular septum of 20 per cent or less This is in agreement with echographic measurements (COHEN et coll)

The angiographically observed increase in thickness are avoided by only measuring the diastolic traction is considerably more marked than according to the calculations of the model This may in part be explained by encroachment of the papillary muscle and the trabeculae during late systole These possible mistakes in the systolic increase in thickness are avoided by only measuring the diastolic thickness and thereafter calculating the systolic thickness according to the principles of even wall thickness and constant myocardial volume (HUGENHOLTZ et coll 1969)

The myocardial wall seems to have a somewhat uneven thickness (MCALPINE) The actual systolic increase in wall thickness may be unevenly distributed The left ventricular myocardial mass in the control group was according to the model 162 g on the average (range 103–213 SD 35 myocardial density 1 05 BARDEEN 1918) These estimates of the myocardial mass in the control group lie within an acceptable range (RACKLEY et coll) even though the heart has an uneven wall thickness

The calculated average end systolic fibre shortening in the control group was 19 1 per cent In vitro stimulation of cat papillary muscle with an isometric myograph showed increasing tension from 70 to 100 per cent of an optimum length whereafter the tension decreased (the optimum muscle length had a resting sarcomere length of 2 18 measured after glutaraldehyde fixation SONNENBLICK & SKELTON 1974) The calculated estimates of fibre shortening are thus within an acceptable physiologic range even though the actual systolic increase in thickness of the heart wall may be unevenly distributed

During systole the posterolateral wall narrows the ventricular cavity making it more and more slit like As shown the free wall fibre shortening is very effective in expelling the stroke volume The work per unit fibre shortening is increased The consequence is work hypertrophy of the free wall

The narrowing of the ventricular cavity during the late part of systole is marked in the apical and middle parts of the cavity The posterior and septal walls actually meet except along an axial small part of the cavity This open part is caused by the transverse concavity In the other parts in which septal and posterior walls meet significant further shortening of the posterior wall is impossible Therefore the apical and middle parts of the posterior wall perform essentially isometric contraction during the latter part of systole with hypertrophy as a consequence

The basal part of the ventricular cavity near the valvar apparatus is deeper than the middle and apical parts The posterior wall therefore runs obliquely from the valvar apparatus to the more shallow middle part relative to the septal plane During con

traction the basal part contracts more concentrically because the contractile part of the circumference is larger in this part of the cavity Thus the basal part of the posterior wall does not move actively in the anterior direction to the same degree as the middle and apical parts Consequently it does not perform late systolic isometric contraction this stimulus to work hypertrophy is thus absent

Towards the middle third of the cavity the most basal part of the posterior wall is transitional in this respect It encroaches upon the septum definitely more than the part attached to the valvar apparatus The most basal part of the posterior wall also moves anteriorly towards the membraneous part of the septum reflected in a late systolic oval shape of the mitral ring But it does not move anteriorly as fast as the middle part because of a larger circumference with a more concentric contraction The effect of this is that during the first half of systole the posterior wall is increasingly tilted relative to the septal plane During the latter part of systole as the most basal part continues its contraction this tilting is reduced

The overall systolic fibre shortening of the most basal part therefore lies more within a normal range The tilting causes the speed of the systolic contraction to appear increased at echography during the first part of the systole and the reduction of the tilting during the latter part produces the echographic impression of the systolic thickness reaching a plateau as described by COHEN et coll They found a total systolic thickening within the normal range However the measured echographic velocity of this thickening was increased during the first half of systole then a plateau was reached No conflict therefore exists between their observations and the present ones but the evaluation of their data is different

IHSS also exists in a non obstructive form (EPSTEIN et coll) The basal part of the left ventricular posterior wall does not have the obstructive stimulus to work hypertrophy either in this variant of the disease This explains why the posterior wall hypertrophy in these cases is uneven the most basal part not being hypertrophic ROBERTS (EPSTEIN et coll) states that an unusual type of distribution of myocardial thickness however is found in patients with the nonobstructive form of the disease In these patients the portion of the left ventricular free wall directly behind the posterior mitral leaflet always is of normal thickness (confirming the echocardiographic findings) even when major portions of the remainder of the left ventricular free wall may be thickened

The microstructural abnormalities of the hypertrophic interventricular septum are not specific but occur also in the free left ventricular wall in IHSS as well as in other conditions with isometric myocardial contraction (BULKLEY et coll 1977 HUTCHINS & BULKLEY WIGLE & SILVER 19/8)

In the free wall of the IHSS left ventricle myocardial anatomic abnormalities characteristic of isometric contraction are observed in non-obstructive cases of the disease in cases with obstruction the myocardium is more normal (MARON et coll 1974) The reason is probably that when subaortic obstruction occurs the metric contraction of the free wall is slowed down considerably in the latter part of systole The obstruction acts like a buffer damping the abrupt isometric contraction which would otherwise occur and which actually occurs when the free wall encroaches upon the septum in non obstructive cases

According to the calculations and the previous argumentation the free left ventricular wall in IHSS has a normal velocity of the myocardial fibre shortening during the first part of systole relative to the systolic time span During the latter part of the systolic period however the free wall performs an essentially isometric contraction except for its most basal part A certain degree of fibre shortening causes the explusion of a larger part of the stroke volume than normally Work hypertrophy of the free wall ensues both for this reason and because of isometric contraction and subaortic stenosis

The fact that a smaller degree of free wall fibre shortening causes the expulsion of a larger fraction of the stroke volume than normally even though the ejection fraction is larger than normally is based on both functional and anatomic abnormalities which may be summarized as follows (1) A non bending septum with no persisting concavity away from the ventricular cavity and with a markedly reduced shortening acting as a suspender for the rest of the wall (2) some increase in the septal thickness narrowing the ventricular cavity (3) myocardial hypertrophy of the non septal wall (4) a long ventricular cavity relative to the width (5) a shallow left ventricular cavity and (6) a somewhat smaller EDV than in normal patients

Conclusion During the first part of the systolic period the myocardial fibres of the free left ven-

cular wall in IHSS shorten with the same speed as normal left ventricular fibres relative to the systolic time span The myocardial contraction causes however the expulsion of a larger fraction of the stroke volume per unit fibre shortening even with the high ejection fraction of IHSS The reasons for this are attributed to the particular geometry of the left ventricle in IHSS

During the latter part of the systolic period the IHSS left ventricular free wall except the part close to the valvar apparatus performs essentially an isometric contraction

SUMMARY

Left ventricular cineangiographic data from 4 patients with idiopathic hypertrophic subaortic stenosis (IHSS) and 10 control patients have been analysed by means of geometric models The myocardial fibre shortening of the free left ventricular wall in IHSS has been compared with the fibre shortening of the left ventricular wall in the control group During the first half of systole the fibre shortening occurs equally fast in the two groups but during the second half it lags clearly behind in the IHSS group *The stroke volume is ejected much faster in the* IHSS group and the ejection fraction is much higher This is caused by several factors related to both functional and anatomic derangements of the left ventricle and the interventriclar septum (1) A hypertrophic septum contracting isometrically with no persisting concavity away from the left ventricular cavity acting as a suspender and the posterior wall encroaching upon the septum in a slit like manner (2) Some increase in septal thickness narrowing the ventricular cavity (3) A hypertrophic non septal ventricular wall (4) A long ventricular cavity relative to the width (5) A shallow left ventricular cavity (6) A somewhat smaller EDV than normal

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ULTRASOUND EXAMINATION OF LESIONS IN THE THORAX

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Various echogenic qualities make possible a dif ferentiation between cystic and solid lesions by ul trasound In the thorax the normally aerated lung parenchyma reflects ultrasound preventing exami nation of intrapulmonary lesions whereas lesions in contact with the thoracic wall are within reach Therefore ultrasound may be used to differentiate effusions possible to drain from organized effusions or solid tumor

Material and Methods

Thirty five patients were examined once or sever al times during one year A grey scale B scan unit with 3 5 and 5 MHz transducers was used The patients were examined in supine and sitting posi tions First a longitudinal scan of the liver was made with the patient supine in order to get a proper setting of the ultrasound apparatus The subphrenic area was then examined When the gallbladder and the intrahepatic vessels were demonstrated without internal echoes with good penetration of the liver the patient was moved to a rotatable chair where longitudinal scans were taken at 2 cm intervals of the dorsal and lateral parts of the hemithorax of interest Ventrally located lesions were more often examined with transverse scans When the diaphragm could be demonstrated its movements were measured with a longitudinal scan in maximum inspiration and expi ration over the mid-dorsal area with the patient in sitting position The two scans were exposed on the same film to facilitate the measurement (Fig 1) The margins of an effusion were marked on the skin of the patient its depth measured (Fig 2) and the deepest spot indicated

Results

Because of failure to drain fluid at repeat tho racocentesis 28 patients were referred for exami nation On films exposed in the lateral decubitus position no free fluid had been demonstrated Echo free encapsulated effusion was diagnosed in 25 of these cases (Fig 2) while in 3 multiple echoes with in the lesion indicated organization of the effusion Successful puncture confirmed the findings in those patients with lesions without internal echoes In another 2 patients pus had been obtained at previous punctures and ultrasound demonstrated organized exudate (Fig 3) In one patient no aeration of the right hemithorax was found on chest films At the ultrasound examination a large amount of fluid was found After thoracocentesis a small cell carcinoma was revealed A malignant lesion was also con firmed in a patient with pericardial effusion (Fig 4) Three patients were referred due to a suggestion of a pericardial cyst which was confirmed in 2 (Fig 5) In the third case a necrotic tumor was demonstrated

Discussion

Ultrasound examination of the thorax during the 1960s and the beginning of the 1970s was performed with A mode equipment measuring pleural effusion and pleural thickening (VIIKERI 1970 GORDON 1973 GRYMINSKI et coll 1976) When B mode and grey scale were available the examinations became more morphologic giving better detail (TAYLOR et coll 1973) However the use of the method is still lim ited due to the reflexion in the aerated lung

Ultrasound examination of the thorax may be per

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Fig 1 Longitudinal scan of the dorsal part of the right hemithorax of a patient with pleural effusion in maximum inspiration and expiration showing diaphragmatic movements



Fig 2 Encapsulated pleural effusion with cm marking Pleural effusion (E) rib (R)



Fig 3 Organized empyema containing multiple echoes

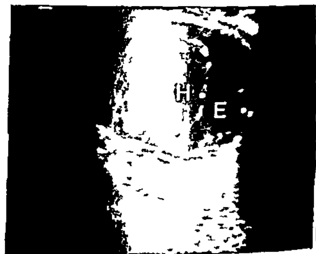


Fig 4 Areas of organization within effusion Puncture yielded only small amounts of hemorrhagic fluid Cytologic examination revealed pericardial carcinomatosis Heart (H) pericardial effusion (E)

formed in various ways BOUTIN et coll (1976) and HIRSCH et coll (1978) used only transverse scans while DOUST et coll (1975) RAVIN (1977) and LAING & FILLY (1978) used only longitudinal scans POIRIER et coll (1975) LANDAY & HARLESS (1977) and CUNNINGHAM (1978) took advantage of both transverse and longitudinal scans Transverse scans seem to be of less value in lesions located dorsally and laterally than in ventrally located lesions due to enhanced rib artefacts It is recommended that both modalities be used to obtain optimum information

The very sensitive modern B scanners are sometimes hard to adjust to avoid creation of false echoes or erasement of the true ones LAING & FILLY used the kidney for adjusting the setting while at this department the liver was used This was considered practical as examination of the liver and the subphrenic area is necessary to avoid missing lesions which may be connected with pleural disease Abscesses intrahepatic or subphrenic are difficult to diagnose by other means Computer tomography has to some extent improved the possibilities for diagnosing such lesions but ultrasound is a faster and also less expensive method It is a well known fact that gas in the stomach often prevents examination of the left subphrenic area and diaphragm The thorax on the left side must be examined from the back

The normally aerated lung covers the diaphragm



a



b

Fig 5 Rounded tumor in the heart liver angle on chest radiography Ultrasound examination showed a cystic lesion confirming the diagnosis pericardial cyst (C) a) Longitudinal scan b) Transverse scan of the lesion

completely and only artefacts are seen on the screen When the diaphragm can be demonstrated from the dorsal aspect of the thorax a pathologic condition must exist COSGROVE et coll (1978) have pointed out the interesting phenomenon that ghost lesions may be observed in the lung region due to changes in the liver because of the reflecting ability of the right hemidiaphragm when covered with normal lung tissue Such lesions do not appear when the abnormalities are present on the thoracic side of the diaphragm

Ultrasound is of great value in the treatment of patients with encapsulated fluid The method has been particularly valuable in those patients in whom multiple unsuccessful attempts at puncture of a possibly fluid filled cavity have been made The method of drawing the margins of the lesion with an extra sign at the deepest place often seems to be of more value than just marking the best spot for puncture (HIRSCH et coll)

Relatively new intrathoracic hematomas may have the same appearance as encapsulated fluid (LAING & FILLY) but no traumatic lesions were encountered in the present material

The differentiation between a solid tumor and a cystic lesion may be facilitated by ultrasound in some cases The demonstration of a pericardial cyst is easy and accurate and puncture may therefore be omitted Moreover the method may be used as a guide in fine needle biopsy of solid lesions adherent to the thoracic wall

SUMMARY

Thirty five patients with intrathoracic lesions were examined once or several times during one year with B scan grey scale ultrasound The difference between encapsulated fluid organized exudate or empyema and solid tumor is discussed as is the procedure of the examination and the possibility of using ultrasound for diagnostic punctures

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ANGIOGRAPHY IN LARYNGEAL CARCINOMA

H SÖKJER and J OLOFSSON

The usual examinations of patients with laryngeal cinoma are mirror laryngoscopy palpation crolaryngoscopy and radiography including con tional films tomography and laryngography ese examinations can usually be relied upon to e adequate information on the superficial exten n of the tumour (OLOFSSON & SÖKJER 1977 9) Vocal cord fixation and radiologic evidence of ilage involvement are indicative of deep tumour asion However these abnormalities do not give cise information on the depth of invasion which ital to know for the correct selection of patients partial surgery with preservation of laryngeal ction Thus other diagnostic methods are ded

he arterial anatomy in normal and carcinoma s laryngeal specimens was investigated (SÖKJER OLOFSSON 1979) in order to elucidate whether delineation of laryngeal carcinoma could be proved by the application of angiography The mal arterial anatomy of the larynx was found to fairly constant Arterial abnormalities in the car oma specimens corresponded to microscopic dence of tumour invasion of the pre epiglottic ace lateral spread to the thyroid cartilage and ead of the tumour outside the larynx by penetrat the cricothyroid membrane Information con rning spread to these regions is important for cision on the surgical management

Angiography has now been applied in a clinical ries in order to assess whether this examination uld be of clinical value No such report appears have been published previously

The larynx is supplied from the superior and ferior laryngeal arteries (RAUBER & KOPSCH 1955) the superior laryngeal artery which is the main laryngeal artery usually originates from the superior thyroid artery although it may originate directly from the external carotid This has been found to be the case in 13 4 per cent of Europeans and in 4 2 per cent of Japanese (ADACHI 1928) The cricothy roid artery another branch of the superior thyroid anastomoses with the superior laryngeal artery lateral to or through the cricothyroid membrane The inferior laryngeal artery a branch of the inferior thyroid artery accompanies the recurrent laryngeal nerve to enter the lower posterior part of the larynx

The superior laryngeal artery usually enters the larynx through the thyrohyoid membrane above the posterior half of the thyroid cartilage (ADACHI) but it may enter through the thyroid foramen in the upper posterior part of the thyroid cartilage This occurred in about 4 per cent of a French material (TERRACOL & GUERRIER 1951) and in about 20 per cent of two Japanese series (ADACHI OKI 1958)

Within the larynx the superior laryngeal artery runs immediately medial to the thyroid cartilage and gives origin to 5 main branches (SÖKJER & OLOFSSON Fig 1) An ascending branch supplies the epiglottis and the vallecula and also gives off branches to the pre epiglottic space one of these vessels often originates directly from the superior laryngeal artery A dorsal branch runs beneath the mucosa of the anterior part of the piriform sinus to anastomose with the medial division of the inferior laryngeal artery in the postcricoid region A ventral branch runs deep to the false vocal cord and laryn

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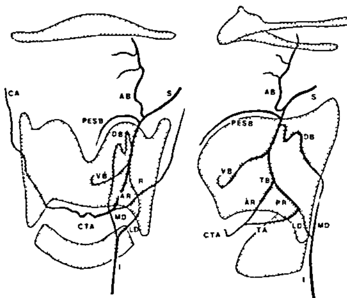


Fig 1 Normal arterial anatomy of the larynx a) A p view b) Lateral view AB=ascending branch AR=anterior ramus CA=cricothyroid artery CTA=anterior cricothyroid arcade DB=dorsal branch I=inferior laryngeal artery LD=lateral division MD=medial division PESB=proximal branch to the pre-epiglottic space PR=posterior ramus S=superior laryngeal artery TA=transverse arcade TB=terminal bifurcation VB=ventral branch

geal ventricle in an anterior direction to terminate above the anterior commissure The superior laryngeal artery ends in a terminal bifurcation where it divides into an anterior and a posterior ramus The level of the terminal bifurcation varies from about 5 mm above the superior surface of the vocal cord to about 5 mm below The anterior ramus runs lateral to the thyroarytenoid muscle in an antero caudal direction towards the anterior part of the cricothyroid space It leaves the larynx lateral to the cricothyroid membrane to anastomose with the cricothyroid artery and with the arteries of the opposite side via the anterior cricothyroid arcade The posterior ramus runs lateral to the lateral crico arytenoid muscle to anastomose with the lateral division of the inferior laryngeal artery The anterior and posterior rami may be linked by a transverse arcade

Material and Methods

Over a two-year period (1976 to 1978) laryngectomy was performed in 11 male patients with laryngeal carcinoma (It was contemplated in one other but not actually carried out) Angiography was performed in 8 of these patients and these constituted the present series The other 3 patients were elderly men with recurrent carcinoma whose treatment would probably not have been influenced by the outcome of angiography

Five cases had primary glottic one case trans glottic carcinoma—probably arising in the supra glottic region—and 2 cases primary epiglottic carcinoma In 2 cases angiography was performed after radiation therapy on detection of a recurrence whereas in the other 6 cases angiography was carried out before any kind of treatment had been given In one case the angiography was performed 2 years before laryngectomy whereas in the other 7 patients it was performed immediately before operation or preoperative irradiation

The following methods of examination were used mirror laryngoscopy palpation and radiography comprising conventional films tomography and laryngography After the radiologic examination direct laryngoscopy was carried out the operating microscope and 90° optical instruments were used (OLOFSSON & SÖKJER)

Angiography was performed on the side that was the more extensively involved by the tumour The common carotid artery was punctured a Hanafee catheter with OD 1 57 mm was inserted so that it entered the superior thyroid artery The tip of the catheter had been shaped as a semicircle about 2 cm in diameter In the first five magnified lateral views were obtained using 0 3 mm focus The injection of contrast medium elicited swallowing with movement of the larynx even when metrizamide was used This necessitated general anaesthesia which was used only in the three last patients The procedure applied in these patients which was considered to be superior was as follows To enable good subtraction to be obtained the films were exposed during apnoea Isopaque Cerebral was used as contrast medium and 3 to 9 ml was injected at a rate of 3 ml/s Three series of films were exposed an ordinary a p a lateral stereographic projection using a 1 0 mm focus and a 12 1 grid with a FFD of 90 cm a lateral view using a 0 1 mm focus and 2 1 magnification The exposure rates were 2 per s for 4 s and then 1 per s for 4 seconds Kodak G film and X omatic screens were used

Angiography was performed in 5 of the 8 laryngectomy specimens

All the laryngectomy specimens were whole organ serial sectioned and the angiographic and microscopic findings were compared



a



b



c



d

Fig Glottic carcinoma with sub and supraglottic extension on the right side fixation of the vocal cord and a metastatic midjugular node Preoperative radiation therapy was followed by wide field laryngectomy in which the right lobe of the thyroid gland was removed and a right neck dissection a) Conventional film lateral view Destruction of the anterior part of the thyro d cartilage b) Laryngography p a view Tumour of the right hemilarynx d Angiography of the right upe r thyroid artery lateral and a p views (subtraction) Superior laryngeal artery (→) Anterior ramus occluded at the terminal b f[illegible] ation (↠) Ventral branch not demonstrated Anter r cr[illegible]othyroid arcade (↔) d placed anteriorly Pooling in a node with met [illegible] (↣)



Fig 3 Same case as Fig 2 Coronal sections a) through the midpart of the vocal cord and b) the anterior commissure Arrows indicate the ulcerated tumour of the right hemilarynx invading the thyroarytenoid muscle (a) and the anterior part of the thyroid cartilage with spread outside the larynx through the cricothyroid membrane (b) c) A p angiography of the laryngectomy specimen Both superior laryngeal arteries demonstrated by injection into the right one Branches distal to the origin of the dorsal branch (⟶) on the right side not demonstrated C cricoid cartilage E=epiglottis T=thyroid cartilage

Comment Two metastatic nodes were found in the neck specimen One normal parathyroid gland was present at the lower pole of the thyroid lobe

Results

In one case the tumour was superficial and the angiographic appearances were normal

In another case the angiographic appearance was considered normal and no cartilage invasion was observed on the conventional films Originally combined treatment was planned but because the tumour regressed rapidly during irradiation and neither the routine examinations nor the angiography indicated deep tumour invasion it was decided to give a full course (66 Gy) When two years later recurrence was observed a lateral low voltage conventional film showed destruction of the anterior thyroid cartilage The patient s general condition was too poor to allow a total laryngectomy No angiography was performed Partial vertical laryngectomy using an anterior commissure technique was carried out (SOM & SILVER 1968) At microscopy invasion of the cartilage was found but no spread beyond the larynx

In 4 cases microscopic evidence of deep lateral invasion existed Corresponding angiographic abnormalities were present in 3 of these (Figs 2–5) and possibly also in the fourth In one of these cases the angiography was also indicative of tumour penetration of the cricothyroid membrane and also of a metastasis in a lymph node In another case (Fig 5) the angiographic changes were subtle but definitely pathologic In one case the films were suggestive of occlusion of the anterior ramus which however could be a normal variant—the anterior ramus being replaced by the transverse arcade (SÖKJER & OLOFSSON Fig 1)

In 2 cases with epiglottic carcinoma the extensive invasion of the pre epiglottic space detected at microscopy was not demonstrated at the preoperative angiography in one of these neither at the angiography of the laryngectomy specimen

Both the normal and the pathologic soft tissues of the larynx displayed more or less marked accumulation of contrast medium in the capillary phase In one case a defect probably represented the tumour (Fig 4) Otherwise the accumulation of contrast medium did not afford conclusive evidence of deep tumour infiltration Slight neovascularity and early venous draining were found in one case

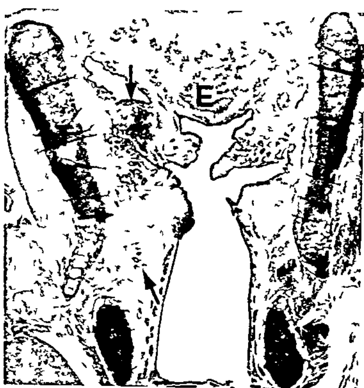
No complications ascribable to the angiography were encountered

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Fig 4 Transglottic probably primary supraglottic carcinoma on the right side of the larynx Vocal cord fixed No evidence of cartilage invasion on the conventional films a) Laryngography p a view Arrows indicate tumour b) Coronal section through the anterior third of the vocal cords Arrows indicate the tumour which has a transglottic distribution and along the thyroarytenoid muscle No invasion of cartilage c) d) Angiography of the right superior thyroid artery lateral and a p view (subtraction) The ventral branch is almost occluded (→) and the anterior ramus (→) is partly filled via the cricothyroid artery Defect in the capillary pool (→ in d) C=cricoid cartilage E=epiglottis T=thyroid cartilage



a



b



c



d

Fig 4 (For legend see opposite page)



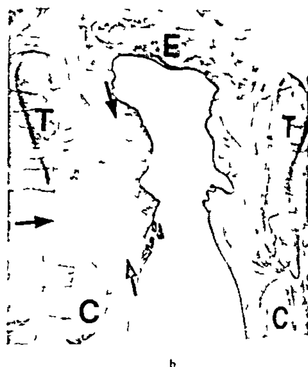


Fig. 5. Glottic, sub- and supraglottic carcinoma on the right side with fixation of vocal cord and cartilage invasion on conventional films. a) Angiography of right superior thyroid artery, lateral view (subtraction). Anterior ramus is irregular (→). Ventral branch normal (↔). b) Coronal section through mid-portion of vocal cords. Tumour (arrows) invades lower part of right thyroid ala. C=cricoid cartilage. E=epiglottis. T=thyroid cartilage.

Discussion

From the previous investigation of the arterial anatomy in laryngeal specimens (SÖKJER & OLOFSSON) it was concluded that angiography might prove a useful aid in determining whether the tumour is approaching the thyroid ala, invading the pre-epiglottic space or the piriform sinus or spreading outside the larynx through the cricothyroid membrane.

Catheterization of the superior thyroid artery was easy to carry out but attempts to catheterize the superior laryngeal artery were unsuccessful and elicited arterial spasm. Selective injection into the superior laryngeal artery should be possible when this vessel originates directly from the external carotid artery.

Most of the angiographic information was provided by the lateral views. Stereoscopic radiography is necessary to distinguish the laryngeal vessels from the superimposed branches of the superior thyroid artery; information obtained from these films was useful in analysing details in the magnification series.

Because the injection of contrast medium into the superior thyroid artery elicited a swallowing with movement of the larynx and hypopharynx—even when metrizamide was used as contrast medium—general anaesthesia was needed (FAGERBERG 1977).

Arterial displacement indicated tumour spread anteriorly through the cricothyroid membrane in one case. Lateral spread was not suggested by such displacement but vascular occlusions were found in 2 cases and possibly also in another case. In 2 of these cases the tumour spread into the thyroid cartilage. Because of the location of the vessels just medial to the thyroid cartilage arterial occlusion indicates that the tumour is only approaching and not necessarily invading the cartilage. Changes in calibre of the arteries suggestive of tumour encasement were present in one case. Tumour neovascularity and early venous draining were not prominent features. A defect within the accumulation of contrast medium visible in the a.p. view in one case (Fig. 4) corresponded to the extension of the tumour in the whole-organ sections. In one case no

conclusions could be drawn concerning the reliability of angiography for delineating the laryngeal carcinoma as it was performed two years before the partial laryngectomy

Thus it is evident that the laryngeal arteries can be demonstrated by angiography Moreover with this technique it is possible to detect abnormal features providing information concerning the deep ly invading tumour that is not supplied by generally applied methods of examination However in 2 cases with epiglottic carcinomas and major invasion of the pre epiglottic space the angiographic appearances were considered to be normal indicating that invasion of the pre epiglottic space may not be possible to assess by angiography In this region computer tomography may provide supplementary information (MANCUSO et coll 1978) In glottic carcinoma angiography may be useful in assessing the lateral and anterior spread However the number of patients is too small for any definite conclusions to be drawn

SUMMARY

Angiography was performed in 8 patients with laryngeal carcinoma The findings suggest that angiography can provide useful information on deep tumour invasion but further experiences are required before any definite conclusions can be drawn

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ADRENERGIC AND CHOLINERGIC RESPONSES IN THE UTEROPLACENTAL VASCULAR BED OF THE GUINEA PIG

N EGUND and A M CARTER

The pregnant uterus of the guinea pig is supplied with blood by radial arteries arising from an arterial loop formed by anastomosis of the ovarian and uterine arteries (EGUND & CARTER 1974 CHAICHAREON et coll 1976) Techniques for the selective catheterization of these two arteries have been developed (EGUND & CARTER) to enable pharmacoangiographic investigations of the uteroplacental circulation in an animal with a discoid haemochorial placenta similar to that of man (ENDERS 1965) The basic adrenergic and cholinergic responses of the uterine and maternal placental vascularity in guinea pigs are now reported

Material and Methods

The material consisted of 76 guinea pigs (Cavia porcellus) of mixed breed They were given pelleted fodder (Astra Ewos Sweden) hay and water ad libitum Tocopherol and selenium (Eselen N vet Ferring Sweden) was added to the drinking water Experience has shown that pregnant guinea pigs on a standard diet without this supplement may exhibit hypotension impaired placental circulation and placental infarction also some dead fetuses are found (INGELMAN SUNDBERG 1949) At examination the guinea pigs weighed between 730 and 1 460 g (mean 1 036 g) The stage of gestation estimated from the mean weight of the fetuses in each litter (DRAPER 1920) ranged from 44 to 66 days (mean 60 days)

General anaesthesia was obtained by the intramuscular injection of sodium pentobarbitone (Mebumal vet ACO Sweden) in an initial dose of 20 mg/kg body weight Rectal temperature recorded with an electrothermometer was maintained at a constant level with the aid of an infrared lamp (Osram Siccatherma 250 W Sweden) Arterial blood pressure was recorded electromanometrically from a catheter in an axillary artery Selective catheterization of the ovarian or uterine artery was performed during magnification fluoroscopy as previously described (EGUND & CARTER) A fine polyethylene catheter (OD/ID = 0 6/0 3 mm Surgimed Denmark) was used for the ovarian artery The intra arterial part of the uterine catheter had a similar dimension but was prepared by drawing out the last 3 cm of a catheter (OD/ID = 1 0/0 6 mm) that provided less resistance to the flow of contrast medium The uterine catheter was advanced from the ipsilateral superficial or deep femoral artery and the ovarian catheter from the right carotid artery

Serial angiography with geometric magnification (EGUND & CARTER) was performed before and at various times after the injection of drugs Each series comprised 7 films exposed at intervals of 1 s followed by a further 5 films at intervals of 2 s The contrast medium used was meglumine metrizoate (Isopaque Cerebral Nyegaard Norway) The volume injected was 0 6 ml for the ovarian artery and

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Fig 1 Schematic drawing of the experimental arrangement An ovarian artery (O) is catheterized from the right carotid artery or a uterine artery (U) from the right femoral artery The catheter is connected to a high pressure syringe (PS) for contrast medium injection Blood pressure in the right axillary artery is recorded with an electromanometer (EM) and rectal temperature with an electrothermometer (ET) An automatic film changer (FC) is placed beneath the animal The lower half of the diagram represents a typical tracing from the potentiometer writer which registers the following variables Time in seconds (T) rectal temperature (RT) contrast medium injection rate (IR) film exposures (EX) and arterial blood pressure (BP)

Fig 2 Application of spillover flowmeter technique to assess uterine blood flow Contrast medium is injected at a known rate through a catheter with its tip in the mouth of the uterine artery U=uterine artery I=iliac artery a) Rate of blood flow equal to rate of contrast medium injection uterine artery completely filled b) Rate of blood flow less than rate of injection resulting in spillback of contrast medium into iliac artery c) Rate of blood flow exceeds injection rate and contrast medium is diluted with blood resulting in unsatisfactory filling of uterine artery

0 8 ml for the uterine artery The contrast medium was injected using a high pressure syringe and its course was registered on a direct writing polygraph so that the exact rate of injection could be determined (Fig 1)

The effect of the following substances was evaluated noradrenaline bitartrate (Apoteksbolaget Sweden) phenoxybenzamine hydrochloride (Dibenyline Smith Kline & French England) acetylcholine chloride (Hoffmann La Roche Switzerland) and atropine sulphate (ACO Sweden) Drugs were injected intra arterially through the angiography catheter Each dose was dissolved in 1 ml isotonic saline solution the molar concentration being adjusted to allow for the dead space of 0 1 to 0 2 ml between the syringe and the catheter tip If a drug was found to alter uteroplacental circulation an attempt was made to establish the smallest dose that could elicit a clearly identifiable response This involved a comprehensive series of preliminary experiments The definitive experiments reported are summarized in the Table

The rate of uterine blood flow was estimated by the spillover flowmeter technique (OLIN & REDMAN 1966 CARTER et coll 1971 Fig 2) The rate of injection of the contrast medium is known and if it is the same as the rate of blood flow in the uterine artery this vessel will be filled completely (Fig 2a) If the rate of injection is too fast a spillback of contrast medium into the iliac artery occurs (Fig

Table

Number of experiments with selective injection of drugs into the uterine and ovarian arteries (pregnant guinea pigs)

Drug	Uterine artery	Ovarian artery
Noradrenaline	5	5
Phenoxybenzamine	6	4
Phenoxybenzamine followed by noradrenaline	6	5
Acetylcholine	8	5
Atropine	4	3
Atropine followed by acetylcholine	7	



a



b



c



d

Fig 3 Serial angiography of the right ovarian artery in a pregnant guinea pig about 48 days post coitum Two films from each series are shown exposed 2.5 s (a, c) and 6.5 s (b, d) after start of contrast medium injection Corpora lutea in the [illegible] (A) and ovarian vein (V) Other symbols as in Fig 4 Control a) Arterial phase with contrast medium in a placental artery The injection rate (10.7 ml/min) exceeds the blood flow as evidenced by spillback into the aorta b) Late placental arterial phase Repeat examination 30 s after selective injection of 25 nmol phenoxybenzamine c) Calibre of the ovarian artery has increased and the arterial phase is somewhat more advanced than in the corresponding control film The injection rate (13.6 ml/min) is in equilibrium with the blood flow demonstrating that the [illegible] increased since the control examination d) The [illegible] placental phase indicates a faster circulation [illegible] second more distally situated placenta



a



b



c



d

Fig 4 (For legend see opposite page)

2 b) If the rate of injection is too slow the contrast medium will be diluted with blood and the filling of the uterine artery will be unsatisfactory (Fig 2 c) The same principle can be used to evaluate ovarian blood flow if it is borne in mind that a minor amount of contrast medium split into the aorta may [illegible] be diluted and therefore not be visible Arterial blood pressure was measured to ensure that [illegible] served changes in blood flow were the re[illegible] altered vascular resistance rather than of cha[illegible]



e



f

Fig 4 Serial angiography of the right ovarian artery in a pregnant guinea pig about 59 days post coitum Two films from each series are shown exposed 4 s (a c e) and 10 s (b d f) after start of contrast medium injection Letters indicate the catheter in the abdominal aorta (C) the kidneys (K) the utero-ovarian arterial loop (L) the ovarian artery (O) placental arteries (P) and radial arteries (R) Control a) Arterial phase The contrast medium has not yet reached the placenta but the dilated radial arteries which supply it are well demonstrated b) Early capillary phase Repeat examination after selective injection of 0 5 nmol noradrenaline c) Arterial vasoconstriction is apparent d) Circulation is markedly delayed compared with the corresponding control film and even in later films less contrast medium in the placental blood vessels indicating impairment of the placental circulation Repeat examination after 25 nmol phenoxybenzamine followed by 0 5 nmol noradrenaline e) No vasoconstriction is evident as after noradrenaline alone instead slight dilatation of the ovarian artery Filling of the placental arteries indicates a more rapid circulation than at control examination f) Later capillary phase than in corresponding control film confirming that the circulation is faster

perfusion pressure In the guinea pig the ovarian and uterine arteries anastomose forming an arterial loop that supplies the ovary and the pregnant uterus The calibre of the arterial loop was assessed at three separate points on each film

Additional information was obtained by measuring the following circulation times From the start of the injection until the point at which contrast medium appeared in placental arteries from this point until the placental capillary phase and from the end of the injection until the point at which contrast medium had disappeared from the radial arteries (arterial washout time cf LINGÅRDH & LUNDSTRÖM 1974) Note was also made of possible changes in the filling of the placentae and of the utero-ovarian vein

Some vasoactive drugs are able to evoke uterine contractions of an intensity sufficient to affect the placental blood supply (CARTER & OLIN 1973) In order to avoid uterine trauma the intra uterine pressure was not recorded in connection with the angiography However if a drug was found to reduce the placental blood supply its effect on the myometrium was checked in separate experiments where the drug was injected selectively into the uterine or ovarian artery during registration of the intra uterine pressure through a sponge tipped catheter (BENGTSSON 1968)

Results

The guinea pigs had a mean arterial blood pressure of 9 3±1 0 kPa (69 8±7 6 mmHg) Selective injection of drugs in the uterine or ovarian artery in doses sufficient to affect uteroplacental circulation resulted in no alteration of systemic blood pressure

Noradrenaline 0 5 nmol/kg evoked a decrease in both uterine blood flow and ovarian blood flow associated with arterial vasoconstriction Severe impairment of the placental blood supply also oc


a


b


c


d

Fig. 5. (For legend see opposite page.)



e



f

Fig 5 Serial angiography of the left uterine artery in a pregnant guinea pig about 54 days post coitum Two films from each series are shown exposed 3 s (a c e) 6 s (f) and 12 s (b d) after start of contrast medium injection Letters indicate the catheter in the external iliac artery (C) a thermistor probe (T) and radial arteries (R) Control a) Arterial phase in which contrast medium has just reached a placental artery (→) Spillback of contrast medium into iliac arteries and their branches reveals that the rate of uterine blood flow is smaller than the injection rate (6 8 ml/min) b) Early placental capillary phase Repeat examination 12 s after selective injection of 0 5 nmol acetylcholine c) Contrast medium is diluted with blood filling of uterine artery and its branches unsatisfactory since the rate of blood flow exceeds the rate of injection (7 5 ml/min) Contrast medium has advanced further in the placental arteries (→) than in the corresponding control film d) Late capillary and venous phase in the placentae which should be compared with the early capillary phase of the corresponding control film Repeat examination after another injection of 0 5 nmol acetylcholine e) Injection rate increased more than twofold (17 5 ml/min) and is in equilibrium with rate of blood flow resulting in good filling of uterine and placental arteries (→) Calibre of uterine artery larger than in the control film f) Early capillary phase 6 s after start of injection almost comparable with control film after 12 s Evidently a signficant increase in rate of uteroplacental circulation

curred considerably less contrast medium reached the placenta than at control angiography and the circulation was sluggish (Fig 4) Lower doses (0 01–0 25 nmol/kg) had no effect except in one experiment where 0 25 nmol/kg noradrenaline caused a slight decrease in the calibre of the uterine artery Intra uterine pressure was unaffected by the selective injection of 1 nmol/kg noradrenaline

The effect of phenoxybenzamine at injection into the uterine artery was variable Thus 25 nmol/kg phenoxybenzamine had no effect in two guinea pigs and caused slight vasodilatation in two others whilst in two experiments vasodilatation an increase in blood flow and a reduction of circulation times occurred The effect at injection into the ovarian artery was more consistent 25 nmol/kg phenoxybenzamine evoked a strong vasodilatation and increased the rate at which contrast medium traversed the placenta (Fig 3)

Noradrenaline 1 nmol/kg had no effect on utero placental circulation when injected into either the ovarian or the uterine artery subsequent to the injection of 25 nmol/kg phenoxybenzamine

The primary effect of acetylcholine was vasodilatation and an increase in ovarian and uterine blood flow (Fig 5) However the calibre of the main ste

of the ovarian artery changed only little compared with the dilatation that occurred in more peripheral arteries This effect was invariably obtained with 5 nmol/kg and was usually produced by as little as 0 5 nmol/kg acetylcholine When the dose was increased to 50 nmol/kg vasodilatation was maintained or accentuated but less contrast medium reached the placentae The motility of the uterus was also affected by this dose of acetylcholine causing a visible shift in position of the blood vessels within a single sequence of films However the magnitude of the myometrial response to acetylcholine varied considerably as determined from intra uterine pressure recordings

No change in blood flow or circulation time was observed either 30 s or 10 min after the injection of atropine into an ovarian or uterine artery Transient dilatation of the uterine artery was sometimes seen after atropine but vessel calibres otherwise remained unchanged

All the effects of acetylcholine were effectively blocked by 10 nmol/kg atropine

When vascular resistance decreased following the injection of acetylcholine or phenoxybenzamine a greater number of placental vessels were often filled (Fig 3) suggesting a shift in the partition of placental blood flow between the ipsilateral uterine and ovarian arteries

Discussion

The effect of adrenergic and cholinergic drugs on the extrinsic arterial supply of the uterus of the guinea pig has been examined in a perfusion preparation by BELL (1968) Although the findings were used in support of a theory concerning the control of uterine vascularity in pregnancy (BELL 1974) they have not been corroborated in guinea pigs with an intact uteroplacental circulation Some experiments have been performed with adrenaline (GIRARD et coll 1971) and atropine (BELL & BROWN 1971) but in neither case was the drug injected selectively into the uterine artery Furthermore although the ovarian artery provides an important part of the uteroplacental blood supply in the guinea pig (EGUND & CARTER) no attempt has been made to evaluate the response of this vessel to vasoactive substances

Noradrenaline increases the resistance to flow in perfused uterine arteries a weak response is obtained with 0 03 nmol and 0 3 nmol produces a clear effect (BELL 1968) The sensitivity of the uterine artery is evidently similar in vivo as vasoconstriction and a reduction of uterine blood flow were observed after the injection of 0 52 nmol noradrenaline (0 5 nmol/kg body weight) A similar response was obtained when the corresponding dose was injected in the ovarian artery These effects of noradrenaline are evidently mediated by α adrenergic receptors as they are inhibited by phentolamine in vitro (BELL 1968) and phenoxybenzamine in vivo

The association of adrenergic nerves with the uterine vessels of the guinea pig has been demonstrated histochemically and their transmitter content apparently decreases during pregnancy (SJÖBERG 1968) Nevertheless when isolated uterine arteries from pregnant guinea pigs are stimulated electrically they are able to release noradrenaline (BELL & VOGT 1971) Further evidence for α adrenergic innervation of the uterus during pregnancy was obtained by giving selective injections of phenoxybenzamine in a dose known to inhibit the response to exogenous noradrenaline When the drug was given in the uterine artery it evoked vasodilatation in four guinea pigs and a gradation in response occurred suggestive of varied sympathetic tonus It should be emphasized that these animals were under light anaesthesia had a normal body temperature and had an adequate arterial blood pressure that was unaffected by the phenoxybenzamine A vasodilator response to phenoxybenzamine has previously been demonstrated in the uterine vascularity of the rabbit (CARTER & OLIN 1972)

Isolated uterine arteries are in a condition of minimum tonus and do not respond to acetylcholine (BELL 1968) If tonus is raised by adding noradrena line to the surrounding bath intra arterial injection of acetylcholine elicits vasodilatation The effect is almost maximum in the dose range 0 55 to 5 5 nmol and a decrease in perfusion pressure is elicited by as little as 55 fmol (BELL 1968) The present results indicate that the uterine artery of the guinea pig is considerably less sensitive to acetylcholine when in a state of physiologic tonus The smallest dose found to evoke vasodilatation or an increase in uterine blood flow was 0 53 nmol (0 5 nmol/kg body weight) This suggests that if a cholinergic vasodilator mechanism exists in the uterus of guinea pigs and other species including man (BELL 1971) its importance may have been overemphasized It is interesting to note that although human uterine arteries appear to receive cholinergic innervation perfused vessels do not respond

to acetylcholine even when their tonus has been raised by noradrenaline (BELL 1969)

An interesting difference was found in sensitivity to acetylcholine between the main stem of the ovarian artery and the remainder of the utero ovarian arterial loop It exhibited little change in calibre on injection of the drug even when the rate of ovarian blood flow increased The rise in blood flow was clearly associated with increased conductance in the uteroplacental vascular bed but it was not possible to assess whether the ovarian vascularity was affected

If a large dose of acetylcholine 50 nmol/kg is injected into the uterine or ovarian artery its immediate effect is to reduce the blood supply to the placentae The increased resistance to flow is evidently presented by the intra uterine part of the vascularity since the extrinsic uterine arteries remain dilated It is probably ascribable to compression of the blood vessels due to myometrial contraction rather than to vasoconstriction

The response of the uteroplacental vascularity to acetylcholine was abolished by the previous injection of 10 nmol/kg atropine confirming that acetylcholine is acting through muscarinic receptors (BELL 1968) BELL & BROWN assigned an important physiologic role to these receptors as they observed a decrease in the calibre of the uterine arteries following the injection of large doses of atropine 144 to 1440 nmol/kg into the aorta It was attempted to confirm their results by selective injection into the uterine and ovarian arteries of 10 nmol/kg atropine a dose that is sufficient to inhibit the response to exogenous acetylcholine No diminution of vessel calibre occurred suggesting that cholinergic innervation is of minor importance as a determinant of uterine blood flow under physiologic conditions This does not preclude the possibility that the utero placental circulation is protected by cholinergically mediated vasodilatation during for instance a rise in sympathetic tonus in response to stress BELL (1968) has clearly documented the extreme sensitivity to acetylcholine of perfused uterine arteries in the presence of noradrenaline

SUMMARY

The effects on uterine and maternal placental circulation of adrenergic and cholinergic drugs injected selectively in the ovarian and uterine arteries of guinea pigs were analysed by serial angiography Noradrenaline 0 5 nmol/kg was found to cause a reduction in both ovarian and uterine blood flow associated with arterial vasoconstriction and impairment of the placental circulation This response could be prevented by α adrenergic blockade with 25 nmol/kg phenoxybenzamine At injection into the ovarian artery phenoxybenzamine alone increased ovarian blood flow and elicited arterial vasodilatation At injection into the uterine artery the response was more variable but vasodilatation was observed in four animals of six Acetylcholine 0 5 to 5 0 nmol/kg evoked an increase in both ovarian and uterine blood flow and arterial vasodilatation When the dose was increased to 50 nmol/kg dilatation of the extrinsic uterine arteries was maintained but the placental circulation was reduced due to concomitant contraction of the myometrium All the effects of acetylcholine could be blocked by prior administration of 10 nmol/kg atropine This dose of atropine did not affect uterine or placental circulation when given alone

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PROTEINURIA FOLLOWING NEPHROANGIOGRAPHY

V Influence of calcium and magnesium ions in non ionic contrast media

S HOLTÅS T ALMÉN K GOLMAN and L TEJLER

The introduction of the tri iodinated contrast media in common use has lowered the risk of renal injury induced by contrast medium but decreased renal function following urography and various angiographic procedures has been relatively frequently reported (STARK & COBURN 1966 SIDD & DECTER 1967 MCEVOY et coll 1970 PORT et coll 1974 ANSARI & BALDWIN 1976 OLDER et coll 1976 TEJLER et coll 1977b MILMAN & GOTTLIEB 1977 HARKONEN & KJELLSTRAND 1977 KRUMLOVSKY et coll 1978)

The decrease in renal function has been measured and quantitated using different techniques and parameters (LASSER 1967 ALMÉN 1971) Proteinuria is one sign of injury to the kidney and it has recently been demonstrated that it regularly occurs after nephroangiography both in man (TEJLER et coll 1977a) and in dog (HOLTÅS et coll 1978a) Proteinuria following angiography was found both when ionic (metrizoate diatrizoate) and non ionic (metrizamide C 29) contrast media were used In attempts to reduce the proteinuria in dogs it was shown that the chemical structure of the contrast medium was of greater importance in causing protenuria than the high osmolality of the contrast medium solution (HOLTÅS et coll 1978b) The experimental substance C 29 induced significantly less proteinuria than the other contrast media tested (HOLTÅS & TEJLER 1979) Analyses of the molecular sizes of the excreted proteins disclosed that the contrast media increased the glomerular permeability (TEJLER et coll 1977a)

The stability of cell junctions in membranes is strongly dependent on the presence of calcium ions (SÖGNEN 1967 ROSE et coll 1977) Addition of calcium and magnesium ions to metrizoate and calcium or calcium and magnesium ions to C 29 have previously (SALVESEN et coll 1967 GOLMAN 1979) been shown to decrease blood brain barrier permeability following selective cerebral angiography Whether addition of these ions to contrast media would also decrease the glomerular leakage of proteins induced by nephroangiography has been investigated and the results are now reported

Material and Methods

Dogs The experiments were performed on mongrel dogs weighing on the average 21 kg (range 12–38 kg) anesthetized with pentobarbitone and breathing spontaneously through an endotracheal tube Arterial and urinary bladder catheterizations were performed as previously described (HOLTÅS et coll 1978a)

The dogs were divided into 3 groups The concentration of urinary albumin was recorded following injection into one renal artery of the non ionic contrast medium C 29 (group I) C 29+CaCl (group II) or C 29+CaCl +MgCl (group III) The number of dogs in the groups the dose and composition of the contrast medium solutions are given in the Table

Urine samples were obtained via the transurethral catheter before and 15 30 and 60 min after the injection

Rats Wistar rats weighing 240 to 350 g were an

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Table

Relative increase of urinary albumin (max postinj conc / preinj conc) in the different experimental groups (Dogs I–III Rats A–E) The concentration of all contrast media solutions was 1 0 mol/l (370 mg I/ml)

Group	No of animals	Injected material	Dose (ml/kg)	Electrolytes (mmol/l) CaCl$_2$	Electrolytes (mmol/l) MgCl$_2$	Relative increase of urinary albumin (median and range)
I	29	C 29	0 5	–	–	49 (1 6–1[illegible] 000)
II	12	C 29	0 5	10	–	3[illegible]5 (8 [illegible] [illegible] 300)
III	21	C 29	0 5	5	[illegible] 5	150 (1 7–4 800)
A	10	Metrizamide	1 0	–	–	[illegible]6 (0 7–[illegible]0)
B	10	Metrizamide	1 0	7 5	–	14 (4–77)
C	10	Metrizamide	1 0	25	–	54 (18–95)
D	10	C 29	1 0	–	–	2 3 (1 1–6 3)
E	10	0 9% NaCl	1 0	–	–	1 5 (0 6–3 7)

Statistical evaluation of differences in relative increase of urinary albumin between the groups I II $p<0.05$ I–III and II–III no significant differences I–D $p<0.005$ A–B no significant difference A–C $p<0.05$ A–D $p<0.01$ D–E $p<0.05$

esthetized with pentobarbitone and placed supine Laparotomy was followed by an incision into the urinary bladder and a polyethylene tube (Intramedic PE 60 Clay Adams) for urine sampling was introduced and sutured in place Another polyethylene tube for contrast medium injection was placed retrogradely in the aorta and sutured in such a position that the tip of the tube was just below the origin of the left renal artery The superior mesenteric artery was ligated in order to avoid the escape of contrast medium via this route The solution to be examined was then injected with a speed of 10 ml/min At this speed the solution was forced to a level 2 to 3 mm above the origin of the right renal artery and flowed through both renal arteries as confirmed on a film exposed one second before the end of the injection

The rats were divided into 5 groups The concentration of urinary albumin was recorded following injection into the aorta of the non ionic contrast medium metrizamide (group A) metrizamide with addition of different doses of CaCl (groups B and C) C 29 (group D) and 0 9% (w/v) NaCl (group E) The number of rats in the groups the dose and composition of the contrast media solutions are given in the Table

Urine was collected before and after the injections during 30 minute periods

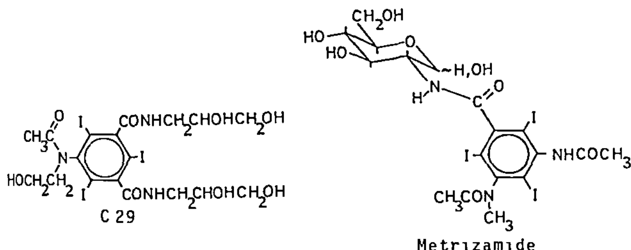
Albumin assays The concentration of albumin and creatinine in the urine was determined as previously described (HOLTÅS et coll 1978a) For the albumin assay in rats goat anti rat albumin antiserum (Cappel lab USA) was used Concentrations of urinary albumin were expressed per gram creatinine thereby relating albumin excretion to glomerular filtration rate Pooled canine and rat plasma was used as standards in the albumin assays They were assigned a concentration value of 100 arbitrary units of albumin per liter

The ratio between the maximum postinjection concentration of urinary albumin and the preinjection value was calculated for each animal For this ratio the term relative increase of urinary albumin is used Differences were considered significant when p values ≤ 0.05 were obtained by the Mann Whitney rank sum test or Wilcoxon s test for paired observations

The structural formulas of the contrast media metrizamide (Amipaque) and C 29 which have been used in the experiments are given in the Figure

Results

Dogs Following unilateral nephroangiography with C 29 significant increases ($p<0.005$) in the concentration of urinary albumin were observed in all groups (Table) Addition of CaCl$_2$ and MgCl$_2$ to a final concentration of 5 mmol/l and 2 5 mmol/l respectively to C 29 did not influence the relative increases of urinary albumin but when CaCl$_2$ was added to a concentration of 10 mmol/l significantly higher relative increases ($p<0.05$) occurred compared with those found following nephroangiography with C 29 alone (Table)



ıemıcal structure of C_9 and metrızamıde

The medıan preınjectıon concentratıon of urınary bumın ın the dogs was 0 51 (range 0 069–3 6) ar trary unıts/g creatınıne

Rats Followıng bılateral nephroangıography with etrızamıde or C 29 sıgnıficant ($p<0\ 05$) ıncreases the concentratıon of urınary albumın were ob-served ın all groups whereas ınjectıon of 0 9% w/v) NaCl dıd not cause such ıncreases (Table) he relatıve ıncreases of urınary albumın were ıwer ($p<0\ 01$) followıng ınjectıon of C 29 than after ıy of the metrızamıde formulatıons Addıtıon of aCl_2 to a final concentratıon of 7 5 mmol/l to ıetrızamıde dıd not ınfluence the relatıve ıncreases f urınary albumın followıng nephroangıography ut when $CaCl_2$ was added to a concentratıon of 25 ımol/l sıgnıficantly hıgher ($p<0\ 05$) relatıve ın reases were observed (Table)

The ınjectıon of C 29 ın rats resulted ın sıgnıfi antly lower ($p<0\ 005$) relatıve ıncreases of urınary ılbumın than ınjectıon of C 29 ın dogs The medıan preınjectıon concentratıon of urınary albumın ın the rats was 6 4 (range 2 7–11) arbıtrary unıts/g creatı nıne

Discussion

Followıng nephroangıography massıve albu mınurıa occurs ın man (TEJLER et coll 1977 a) and ın dog (HOLTÅS et coll 1978 a) The present results show that the non ıonıc contrast medıa metrızamıde and C 29 also ınduce albumınurıa ın rats

The preınjectıon concentratıons of urınary albu mın ın the rats were about 10 tımes hıgher than ın the dogs Thıs mıght be the reason why sıgnıficant ly lower ($p<0\ 005$) relatıve ıncreases of urınary albu mın followıng ınjectıon of C29 occurred ın rats than ın dogs

C 29 ınduces sıgnıficantly less albumınurıa follow ıng angıography ın dogs than metrızamıde (HOLTÅS & TEJLER) In the present experıments ınjectıon of C 29 ınduced sıgnıficantly lower ($p<0\ 01$) albumın urıa than metrızamıde also ın rats Thıs ındıcates that the chemıcal structure of the contrast medıum ıs more ımportant as a factor causıng albumınurıa than the osmolalıty sınce solutıons of C29 and metrızamıde have about the same osmolalıty at equal ıodıne content

Contrast medıa ıncrease the permeabılıty of the blood braın barrıer durıng cerebral angıography (JEPPSSON & OLIN 1975 RAPOPORT 1976) and a pro tectıve effect has been observed when calcıum and magnesıum ıons were added to the ıonıc contrast medıum metrızoate (SALVESEN et coll) and the non ıonıc C 29 (GOLMAN) In the present ınvestıgatıon no such benefıcıal effect on the glomerular membrane was found sınce addıtıon of calcıum and magnesıum ıons to C 29 ın dogs and calcıum ıons to metrızamıde ın rats dıd not reduce the albumınurıa followıng angıography When calcıum ıons were added to C 29 ın hıgher concentratıon (10 mmol/l) ın dogs and to metrızamıde (25 mmol/l) ın rats the albumınurıa ın creased sıgnıficantly

Calcıum ıons are ımportant components of the desmosome structure whıch ıs ınvolved ın the cell to cell adhesıon and depletıon of calcıum ıons by chelatıng agents causes separatıon of cell junctıons ın some membranes (SOGNEN ROSE et coll) Thıs mıght be the mechanısm responsıble for the benefi cıal effect of calcıum ıons on the permeabılıty of the blood braın barrıer durıng cerebral angıography

The present results indicate that other mechanisms are involved in the increased glomerular permeability following nephroangiography since no beneficial effect was observed after addition of calcium ions The increased permeability of the glomerular membrane when high concentrations of calcium ions were added to the contrast media cannot be explained at present

SUMMARY

The influence on albuminuria following nephroangiography was *investigated* after addition of Ca^{2+} to the non ionic *contrast medium* metrizamide (Amipaque) in the rat and after addition of Ca or Ca and Mg^{2+} to the experi*mental non* ionic contrast medium C 29 in the dog When Ca^{2+} or Ca and Mg^{2+} were added to metrizamide or C 29 in concentrations two to three times the plasma level *no influence* occurred Higher concentrations of Ca^{2+} (10–25 *mmol/l*) in the metrizamide or C 29 solutions resulted in increased albuminuria

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PROTEINURIA AFTER SELECTIVE NEPHROANGIOGRAPHY IN MAN

Comparison of three contrast media

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Proteinuria following angiography as an indication of possible kidney injury has only lately been noticed in man (TEJLER et coll 1977) They reported massive proteinuria after intraarterial injection into the kidney of meglumine metrizoate in 25 of 28 patients In dogs HOLTÅS & TEJLER (1979) demonstrated proteinuria not only after use of meglumine metrizoate but also after meglumine diatrizoate and metrizamide The present investigation deals with the possible occurrence of proteinuria following aortography and selective nephroangiography in a clinical series of patients Three different contrast media were used

Material and Methods

The material consisted of 45 males and 15 females referred for routine nephroangiography Premedication 0 6 mg of atropine and 10 mg of diazepam was given Lumbar aortography using 40 ml of contrast medium preceded the selective examination at which 10 to 30 ml of medium was injected into the renal artery uni or bilaterally The contrast media used were Isopaque Cerebral (meglumine metrizoate 590 mg/ml and Ca metrizoate 11 mg/ml with an iodine content of 280 mg I/ml) Urografin 60 (Na amidotrizoate 80/mg/ml meglumine amidotrizoate 520 mg/ml with an iodine content of 292 mg I/ml) and Amipaque (metrizamide 280 mg I/ml)

The procedure was the same in all patients The contrast medium to be used was taken from a predetermined random table No differentiation between angiographically normal and abnormal kidneys has been made In 4 patients phlebography of the inferior vena cava (120 ml of contrast medium in each patient) was performed but otherwise no additional angiographic procedure The mean total amount of contrast medium used in each patient was 115 ml range 45 to 350 ml The sampling and analysis of urine was performed immediately before 2 hours 24 hours and when possible 2 or 3 days after the procedure All samples were kept frozen at −20 until analysed At that time the type of contrast medium used was not known

The following analyses were carried out on the collected material

Total protein (BRADFORD 1976) Coomassie brilliant blue G method was applied utilizing a set of reagents manufactured by Bio Rad Laboratories California USA The influence of the contrast media on the absorbance (A_{595}) of the dye protein complex was of no significance

Creatinine was quantitated by the standard Technicon SMA 12/60 method

Albumin (mol wt 65000) Immunoglobulin G (IgG) (mol wt 150000–160000) and α macroglobulin (mol wt 725000) These were assayed using the Mancini single radial immunodiffusion (SRID)

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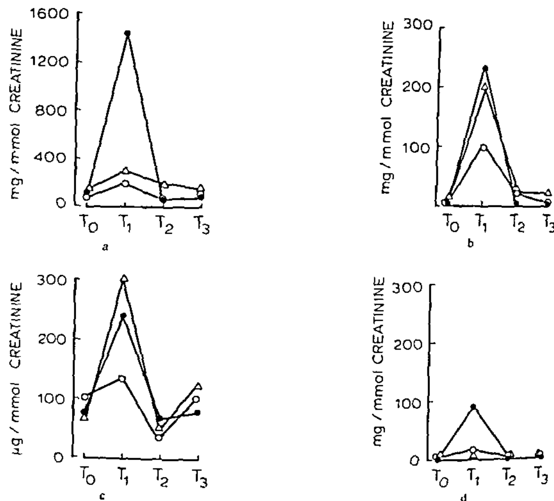


Fig 1 Median values of a) total protein b) albumin c) β_2 microglobulin and d) IgG in urine from patients examined by selective nephroangiography before (T_0) 2 h (T) 24 h (T_2) and 2 to 3 days (T_3) after injection of contrast media ● Isopaque Cerebral Amipaque Δ Urografin 60%

technique (MANCINI et coll 1965) The LC (low concentration) immunodiffusion *Partigen plates* (Behring AG) were applied for the analyses

β-microglobulin (mol wt 12000) (PETERSON & BERGGÅRD 1971) β microglobulin was estimated by the radio-immuno assay Phadebas test (Pharmacia Sweden)

Protein concentrations were calculated as mg protein/mmol creatinine for total protein albumin and IgG globulin and as µg/mmol creatinine for β microglobulin

None of the contrast media interfered with the determinations of proteins when added to urine up to a concentration of 50 per cent

Results

Most patients had slightly elevated values of total protein in urine before angiography As the aim of the investigation was to evaluate the effect of injection into the renal artery no attempt was made to evaluate whether the proteinuria was pathologic o physiologic

Wide variations in total protein values were ob served both before and 2 hours after injection o contrast medium with a range of 0 to 4 300 mg/mmol The high correlation between total protein IgG an albumin appears in Table 1

Patients with albuminuria also excreted IgG β

Table 1

Correlations between different proteins in urine from all patients before injection of contrast medium n=49 The correlations were calculated from log transformed values (Spearman correlation coefficients)

	Albumin	β microglob	IgG
Total protein	0 70	0 01	0 64
Albumin		0 15	0 [illegible]
β_2 microglobulin			0 14

p<0 0001

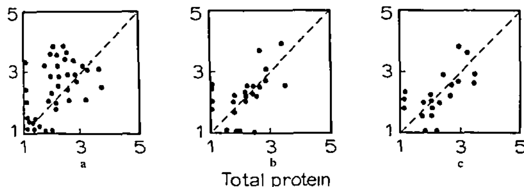
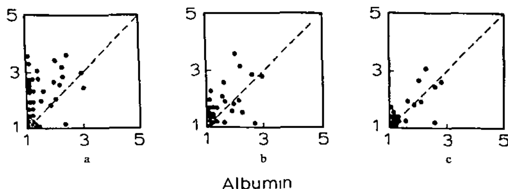


Fig [illegible] Scatter diagram of the correlations of the values of total protein in urine in patients examined by selective nephroangiography before (abscissa) and after (ordinate) injection of contrast media a) Values after [illegible] h (n=50 r=0 4[illegible] p=0 001) b) After [illegible]4 h (n=36 r=0 56 p=0 0001) c) After 2 to 3 days (n=21 r=0 59 p=0 001) All values given as log transformed values (mg/mmol creatinine)



[illegible]ig 3 Scatter diagram of all albumin values before (T) and after [illegible] h (T) [illegible]4 h (T_2) and [illegible] to 3 days (T_3) All values given as [illegible]og transformed values (mg/mmol creatinine) Abscissa corresponds to T values The ordinate corresponds to T T_2 and T_3 values respectively a) n=48 r=0 22 p=0 071 b) n=37 r=0 67 p=0 00001 c) n=2 r=0 75 p=0 00003

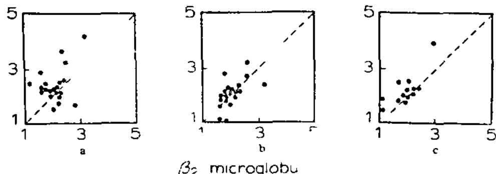


Fig 4 Scatter diagram of β_2 microglobulin values at T (abscissa) and T T_2 and T (ordinate) All values are log transformed (μg m[illegible] [illegible]nine) a) n=46 r=0 44 p=0 0009 b) n=35 r=0 54 [illegible] 0 0004 c) n=[illegible]4 r=0 6 p=0 0006

Table 2

Effects of individual contrast media on the changes in protein excretion 2 hours after selective nephroangiography and aortography (between T_0 and T_1) β_2-microglobulin is given as g/mmol creatinine other proteins as mg/mmol creatinine

Protein	Contrast medium	Number of patients with			Increase (median)	95% confidence interval of changes of proteinuria
		Decrease	No change	Increase		
Total protein	Isopaque	1	0	16	1270	131 2430
	Amipaque	5	0	10	133	−30–100
	Urografin	4	3	11	80	0–300
Albumin	Isopaque	2	4	10	102	0–1690
	Amipaque	3	0	12	70	7–700
	Urografin	5	2	10	76	−10–240
β_2 microglobulin	Isopaque	3	0	13	120	7–708
	Amipaque	5	0	9	18	−77–477
	Urografin	1	0	15	110	35–1211
IgG	Isopaque	1	6	10	90	0–700
	Amipaque	2	5	8	4	0–30
	Urografin	2	8	7		0–50

$p<0.01$ (Wilcoxon one sample test)
$p<0.001$

microglobulin and other proteins were not correlated possibly due to the fact that the concentration of β microglobulin was 3 orders of magnitude less than albumin (Fig 1) Two hours after angiography the median values of total protein albumin and β microglobulin increased significantly (Fig 1) Median values of total protein after Isopaque was significantly higher than after the other contrast media (Fig 1a) However no significant differences were found in the increase of albumin IgG and β microglobulin after angiography within the patient groups receiving any particular contrast medium All protein levels returned to preangiographic values within 24 hours and remained so at the 2nd or 3rd day control The slight increase (Fig 1) in β microglobulin 2 to 3 days after angiography was not statistically significant Fig 2 demonstrates a significant correlation between the preangiographic and the 2 h 24 h and the 2 or 3 day values of total protein A considerable albumin excretion occurred in many patients 2 h after angiography (Fig 3) At this time no significant correlation between T_0 and T_1 values for albumin was found but it became significant after 24 h (T) and remained so at day 2 and 3

Two h after angiography β microglobulin had increased moderately (Fig 4) but the values were significantly correlated with the preangiographic values and remained so at 24 h and day 2 and 3 The increase in IgG was small and no meaningful correlation was obtained

α macroglobulin was not found in urine from any patient at any time

The results indicate a selective increase in glomerular permeability shortly after injection of contrast medium into the renal artery This increase was in the present material completely reversible in almost all patients

The calculated changes in urinary protein excretion 2 h after angiography for each contrast medium are given in Table 2 The increase in total protein was highly significant after Isopaque but of no significance after either Urografin or Amipaque

A small but significant ($p<0.01$) increase in albumin excretion was found after Isopaque whereas the increase after Urografin and Amipaque was not statistically significant

β microglobulin increased significantly ($p<0.01$) after Urografin and Amipaque A similar increase in IgG excretion was found exclusively after Isopaque ($p<0.01$) No persistent proteinuria was observed after any contrast medium (Figs 1–4)

Discussion

The results indicate that selective nephroangiography using Isopaque Urografin or Amipaque

ed by a transient increase in glomerular per ity and moderate decrease in tubular reab n in the kidney The changes are somewhat marked after Isopaque The transient nature of anges indicates that no persistent lesions are Using iodopyracet and metrizoate IDBOHRN RG (1954) IDBOHRN (1956) BERG et coll , KIRKLAND (1959) KIRKLAND & HASLOCK 61) reported albuminuria after nephroangio aphy but TEJLER et coll reported the phenomenon o after metrizoate in man and HOLTÅS & TEJLER n diatrizoate metrizoate and metrizamide also dogs Possible side effects of nephroangiography both man and animal have been discussed by NG et coll (1963) GRAZI et coll (1967) TALNER coll (1972) TEJLER et coll offer two explana ns for the fact that proteinuria has not been re rted before their report

The proteinuria induced reaches its maximum thin few hours after angiography and is of limited ration Immunologic assay not influenced by the gh concentration of contrast medium is needed for e recognition of the proteinuria

Proteinuria caused by nephroangiography is main due to an increase in glomerular permeability as monstrated by the protein assay data In addition e degree of albuminuria observed cannot be used by impairment of merely the tubular reab rption (HARDWICKE et coll 1970) An increase in e glomerular permeability is further demonstrated the presence of IgG in urine (mol wt 150 000) rmally retained by the glomerular barrier (STRO R & WALDMANN 1974) The glomeruli exhib ed some sort of selectivity in the protein filtra on as demonstrated by the differences in clear nce of IgG and albumin (RENNIE 1971 HARD ICKE et coll) Furthermore as α macroglobu n (mol wt 725 000) was not present in any urine ample gross vascular injury in the kidneys is un kely

In normal patients β microglobulin (mol wt ?000) passes through the glomerular filter before it s catabolized by the renal tubular cell (RAVNSKOV 973) The samples containing high concentration of β microglobulin had similarly high concentrations of albumin The increase in β microglobulin may be explained by a probable overload of tubular reab sorptive capacity due to elevated glomerular protein leakage (HARDWICKE et coll RENNIE) and does not necessarily mean an actual lesion of tubular cells The decrease of β microglobulin has parallelly fol lowed that of albumin further supporting the con clusion drawn

BROMAN & OLSSON (1948) and ZINNER & GOTTLOB (1959) have demonstrated that intravascu lar injection of contrast medium can change the epithelial morphology and vascular permeability Similar effects are likely to occur in glomerular capillaries BERG et coll demonstrated injury to the tubular epithelium in the rabbit after intraarterial injection of acetrizoate iodopyracet and diproti zoate but no changes occurred after diatrizoate EVENSEN & SKALPE (1971) using metrizoate in rabbits observed a moderate increase in the mitotic activity of tubular cells indicating healing after tubular lesions Extensive investigations on the molecular and cellular levels are needed to reveal the mechansisms of the proteinuria following angio-graphy

SUMMARY

The proteinuria following aortography and selective nephroangiography in 60 patients using Isopaque Cerebral Urografin 60% and Amipaque was investigated The results indicate an increase in glomerular permeability and possibly an overload of tubular reabsorptive capacity after angiography The changes are transient No permanent injury to the kidney appears to occur

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CONTRAST ENHANCEMENT PHARMACOKINETICS IN EXPERIMENTAL PANCREATITIS DIABETES AND SUBCUTANEOUS GRANULOMA

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Contrast enhancement of the pancreas in computer tomography has been of only limited aid in the clinical differential diagnosis or pancreatic lesions (KIRKPATRICK et coll 1978 GERHARDT et coll 1979) Therefore animal experiments were designed to examine the calculated contrast enhancement in experimental pancreatitis and diabetes in the rat For comparison experimental subcutaneous granulomas were examined as well The effect of time upon the amount of contrast medium within the pancreas and other tissues following the intravenous injection of the contrast medium was analysed Preliminary results have been presented in part previously (KORMANO et coll 1979)

Materials and Methods

Sixty Sprague Dawley rats 3 months old were used 20 each with diabetes pancreatitis and granulomas

In order to induce diabetes an intravenous injection of Streptozotocin (60 mg/kg) was given 30 days before the pharmacokinetic experiment All the rats became diabetic and had permanent glucosuria

Pancreatitis was induced after laparotomy under intraperitoneal pentobarbitone anaesthesia A blunt needle was passed through the duodenum through the papilla of Vater into the pancreatic duct and the common bile duct was temporarily occluded with an atraumatic clamp to prevent regurgitation into the biliary ducts Olive oil (0 1 ml) was injected in 30 seconds after which the laparotomy incision was closed Every animal developed pancreatitis with pancreatic oedema peritoneal fluid and typical calcifications Twenty hours after induction of the experimental pancreatitis ^{1} I diatrizoate and ^{131}I albumin were injected for the pharmacokinetic experiments Eight rats died after the injection and only 12 could be used in the experiments

In the 20 rats used as the control series sponges measuring 1 cm×1 cm×0 5 cm were implanted subcutaneously in the left anterior abdomen 10 days before the pharmacokinetic experiments in order to produce a well matured granulomatous tissue response (DOHERTY et coll 1977) Samples were taken both from the granulomatous tissue adhering to the sponge and from the fluid within the sponge as well as from the pancreas for control

Under intraperitoneal pentobarbitone anaesthesia a mixture of unlabelled and ^{12} I meglumine diatrizoate (Angiografin) mixed with ^{131}I human serum albumin (The Radiochemical Centre Amersham England) was injected into each animal in 5 seconds The meglumine diatrizoate concentration in the mixture was 512 mg/ml the dose per rat 1 300 mg/kg (612 mg I/kg) and activity 2 03 GBq/ml (54 8 μCi/ml) Corresponding values for the human serum albumin were 1 92 mg/ml 4 86 mg/kg and 2 03 GBq/ml (54 8 μCi/ml) The animals were killed either 40 seconds or 2 5 15 or 60 min by removal of the heart at thoracotomy The following samples were taken mixed blood from the thoracic cage and tissues from

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Table

The calculated contrast enhancement (HU) and distribution volumes of diatrizoate and albumin in normal diabetic and pancreatitic pancreases as well as in granuloma tissue at various times after intravenous injection

Tissues			Time 40 s	2 min	5 min	15 min	60 min
Pancreatic tissue							
Control series	Contrast enhancement	HU ± SEM	33 4±1 4	22 [illegible]±1 8	[illegible]1 6±4 [illegible]	11 8± [illegible]0	4 [illegible] 0 4
	Contrast distribution volume	% ± SEM	19 5±1 1	19 6±1 9	28 3±5 4	25 [illegible]±[illegible] 5	[illegible]0 1±[illegible]3 0
	Albumin distribution volume	% ± SEM	3 3±0 4	3 6±0 3	3 2±0	3 4±0 1	4 3± 0 4
Diabetes series	Contrast enhancement	HU ± SEM	[illegible]4 4±0 8	20 4±[illegible] 0	14 4±0 4	11 4±0 8	7 0± 3 0
	Contrast distribution volume	% ± SEM	15 0±1 2	18 5±1 7	[illegible] 7±0 8	[illegible]3 7±1 8	30 1± 4
	Albumin distribution volume	% ± SEM	3 4±0 5	3 8±0 5	4 8±0 4	4 5±0 4	4 8± 0 6
Pancreatitis series	Contrast enhancement	HU ± SEM	48 4±2 2		34 6±		9 6± [illegible]
	Contrast distribution volume	% ± SEM	27 5±1 0		41 6±4 [illegible]		7 [illegible] 4 [illegible] 9
	Albumin distribution volume	% ± SEM	2 5±0 3		[illegible] 8±0 [illegible]		7 9± 1 7
Granuloma tissue							
Control series	Contrast enhancement	HU ± SEM	18 4±2 0	30 0±3 6	31 6±0 8	[illegible]9 4±[illegible]	9 6± 1
	Contrast distribution volume	% ± SEM	10 7±1 0	26 7±4	41 6±1 1	64 3±5 4	174 6±68 5
	Albumin distribution volume	% ± SEM	1 5±0 1	1 8±0 1	[illegible] 3±0 3	[illegible]±0 1	3 4± 0 5

pancreas liver spleen kidney (renal pelvis excised and drained) stomach duodenum and rectus abdominis muscle The samples were placed in preweighed test tubes capped weighed and the ^{125}I and ^{131}I activities measured as described in detail previously (DEAN et coll 1978) The total tissue iodine content was calculated from the activity of the tissue samples The potential contrast enhancement in Hounsfield units at 120 kV peak was then estimated from the iodine concentration using the data of HINDMARSH (1975) Contrast distribution volume was calculated by dividing each tissue contrast concentration by the blood concentration as described previously (DEAN et coll)

Results

While the control animals carrying granulomas were healthy both the diabetic and the pancreatitic animals were seriously ill The average plasma concentrations of contrast medium were similar in all groups

Contrast medium accumulation in the pancreas (Table) The highest contrast concentration and calculated enhancement of the pancreas was observed at 40 seconds in each experimental group No significant difference was observed between the enhancement of normal and diabetic pancreas but in pancreatitis a markedly increased accumulation throughout the one hour observation period (Fig 1) was found The volume of distribution in the pancreas was likewise nearly identical in control and diabetic rats for the first 5 min against a larger distribution volume in pancreatitis (Fig 2) At one hour a very large pancreatic volume of distribution (about 70%) was found with a large variation in both control and pancreatitic rats but a relatively low pancreatic distribution volume (30%) in the diabetic rats The distribution volume of albumin representing the intravascular volume was of the same magnitude in the pancreas in the three experimental groups Thus there was no evidence of capillary breakdown and albumin leakage in the pancreatitic animals indicating that the accumulation of con

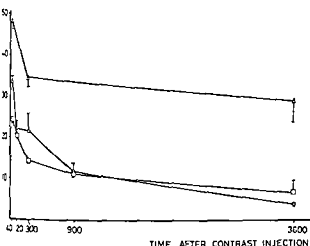


Fig 1

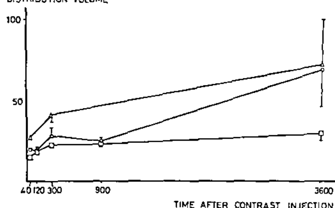


Fig 2

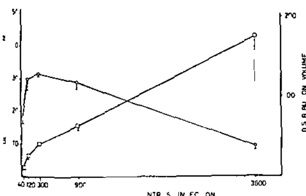


Fig 3

Fig 1 Calculated contrast enhancement (HU ± SEM) of rat pancreas in relation to time (seconds) after intravenous injection of 1 300 mg/kg diatrizoate △ Pancreatitis ○ Control □ Diabetes

Fig 2 Distribution volume (% ± SEM) of diatrizoate in rat pancreatic tissue after intravenous injection (seconds) △ Pancreatitis ○ Control □ Diabetes

Fig 3 Calculated contrast enhancement (HU ± SEM) and distribution volume (% ± SEM) of diatrizoate in experimental subcutaneous granuloma of the rat after intravenous injection (seconds) ○ Contrast enhancement □ Distribution volume

trast medium occurred in the oedematous extracellular space in pancreatitis

Contrast medium accumulation in granuloma (Table Fig 3) In the granuloma tissue the accumulation was delayed and prolonged relative to the pancreas and to other tissues examined with the highest calculated contrast enhancement obtained at 5 min The distribution volume of contrast medium rose rapidly and steady throughout the experiment At one hour the concentration of medium in the granuloma tissue was higher than that in the blood Accumulation into the granuloma exudate was the same as that in the granuloma tissue The albumin distribution readings were low indicating relatively sparse undamaged vascularity responsible for delayed wash in and wash-out of the contrast medium into the granulomatous tissue and exudate

Neighbouring organs of the pancreas The contrast medium kinetics in the neighbouring organs (liver spleen kidney stomach duodenum abdominal muscle) and in the plasma did not differ as far as accumulation distribution or albumin space was concerned when the control diabetic or pancreatitic animals were compared

Discussion

The kinetic behaviour of contrast medium in the control pancreatic tissue was nearly identical to that published previously in a report dealing with contrast media kinetics in normal tissues (DEAN et coll) Streptozotocin causes irreversible destruction of the beta cells (JUNOD et coll 1969) which are the principal component of the pancreatic islets In 30 days diabetes causes no microscopic changes in the exocrine pancreas or its vascularity which comprise the main part of the pancreatic tissue mass (KIVISAARI 1979) The absence of significant change in the kinetic behaviour of the contrast medium in the pancreas following experimental diabetes is therefore no surprise providing that the general hemodynamic balance is not markedly inter

fered with by other consequences of diabetes KIVISAARI also suggested that vascular alterations may occur following long term diabetes especially in muscular vessels but such morphologic alterations were not reflected in the contrast enhancement of the individual tissues

Pancreatitis induced by olive oil is relatively mild It produces a patchy inflammation with interstitial oedema and increased blood flow in the pancreas (PAPP et coll 1966 GOODHEAD 1969 KIVISAARI) The contrast enhancement either calculated or measured from clinical scans does not reflect increased blood flow unless a concomitant marked increase in the contrast containing blood volume of the organ occurs The present results show no increase in the blood volume of the pancreas in the pancreatitic rats although flow changes may have occurred The increased contrast medium accumulation in this situation probably results from the distribution of the medium into an enlarged interstitial fluid space representing oedema

The absence of uniformity of the pancreatitis produced in the rats is reflected in the data However under such experimental conditions the abnormalities are likely to be much more uniform than those occurring clinically As demonstrated by the present experiment changes occur in the tissue contrast kinetics caused by mild acute pancreatitis which theoretically could be detected by contrast enhanced CT scanning Several limiting technical factors artefacts and inhomogeneity of the lesions interfere with their detectability in clinical CT and make kinetic contrast enhancement examination of pancreatitic patients with a slow body scanner unrewarding (KIVISAARI et coll 1979)

The granuloma tissue contrast medium kinetics was completely different from that of the normal diabetic or pancreatitic pancreas and the neighbouring tissues In the stage of development of the experiment granuloma tissue was characterized by a delayed wash in and wash-out of the medium into a poorly vascularized large interstitial fluid volume In clinical practice such a phenomenon is commonly observed in brain lesions where the absence of background enhancement makes contrast medium accumulation easily detectable (GADO et coll 1975 STEINHOFF & AVILES 1976 LEWANDER et coll 1979) Delayed and intense enhancement also occurs for example in the thickened walls of a pancreatic pseudocyst (KIRKPATRICK et coll) but rapid renal excretion of the contrast medium does not usually allow significant uptake into the cyst fluid Some contrast medium may enter into the glandular lumen of the exocrine pancreas itself which would account for the excessively high distribution volume readings at one hour in the present experiments Why such phenomena did not occur in diabetic rats is not readily explainable

The present experiments show increased contrast enhancement in the pancreas in pancreatitis That such an increase has not been clinically appreciable may result from scanning artefacts and inability of presently available scanners to resolve or demonstrate sufficiently small differences in contrast enhancement A general lack of appreciation of the importance of the time course of contrast enhancement and the difficulty in quantitating contrast enhancement at specific times after injection are undoubtedly also contributing factors Improvements in scanner design particularly allowing entire organs to be scanned immediately after contrast injection (ROBB 1978) should improve the clinical application of contrast enhancement Arterial infusion of a contrast medium during scanning (HACKER & BECKER 1979 PRANDO et coll 1979) greatly raises the level of enhancement and improves its clinical usefulness in slow scanners Further experimental work to define contrast enhancement in pathologic conditions is needed to direct clinical attention to its potential for differential diagnosis

SUMMARY

Contrast medium concentration in the pancreas as a function of time after intravenous bolus injection was measured in 12 rats with oil induced acute pancreatitis 0 rats with Streptozotocin induced diabetes and 0 rats with subcutaneous granuloma induced by sponge whose pancreatic tissue was used as a control No significant effect of diabetes was observed Calculated distribution volume and contrast enhancement in the pancreas were increased in pancreatitis relative to diabetes and controls The increased enhancement was due to a relatively higher accumulation into the extravascular fluid considered to represent pancreatic oedema An even more marked and delayed enhancement was observed with the granuloma tissue and exudate apparently on a similar basis There appears to be a possibility of differential diagnosis of some pancreatic lesions using contrast enhanced CT

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RADIOLOGIC EVALUATION OF CHONDROMALACIA PATELLAE

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Several morphometric methods for the evaluation ' chondromalacia patellae at radiography have :en introduced in the past (WIBERG 1941 FUR AIER 1952 BRATTSTRÖM 1960 FICAT & BIZOU '72 STOUGÅRD 1975) The measurements sug sted are the relationship in size and the angulation tween the medial and lateral aspects of the patello moral joint and variables representing the size and iape of the patella itself Normal values have also :en calculated for some of these variables (FICAT BIZOU) Subchondral sclerosis of the patella has :en suggested as indicating chondromalacia (FUR AIER DEPALMA 1954 FICAT et coll 1972) In ldition to such morphometric measurement it was :cided to include measurement of the position of e patella (patella alta BLACKBURNE & PEEL 1977) inally in investigations of chondromalacia patellae this department a shallow excavation centrally in ie subchondral bone of the patella has been con idered to be related to chondromalacia

A series of morphometric variables in relation to n established diagnosis of abnormalities in the pa :llar joint surface is now reported

Material and Methods

The material consisted of 66 patients 33 men and 3 women with suggested abnormalities in the patel o-femoral joints Arthroscopy operation or both has been performed in all cases In conjunction with the arthroscopy or the arthrotomy the abnormali ties of the patello femoral joints were classified ac cording to OUTERBRIDGE (1961) as follows

Grade I Light brown yellow discolouring the cartilage yields to the touch of the arthroscope or a blunt instrument no fragmentation or fissuring

Grade II Fragmentation and fissuring in an area of 1 3 cm or less

Grade III Fragmentation and fissuring in an area of more than 1 3 cm

Grade IV Erosion of the articular cartilage down to the subchondral bone This grade cannot be dis tinguished from patello femoral arthrosis

With this classification the patients were distri buted as follows Normal patello-femoral joint 23 patients (=normal) chondromalacia patellae grade II and III 26 patients (=chondromalacia) and chondromalacia patellae grade IV or patello-femoral arthrosis 17 patients (=arthrosis)

Only patients in whom before the arthroscopy or arthrotomy radiography with a fairly good lateral and axial view of the patella had been performed were included otherwise the radiography followed the standard procedure and no films were obtained specially for this investigation No radiologic ab- normality indicating gonarthrosis was observed on the films After this selection all films were mixed and evaluated blindly with regard to the diagnosis The variables recorded appear in Fig 1 The sclero sis was measured and classified as the extent of scoliosis divided by the patellar joint surface on the lateral film and the degree of excavation was classi fied as non existent possible or obvious

Results

No difference was found between patients with normal patello-femoral joints patients with chond romalacia and patients with arthrosis or grade IV chondromalacia (Table 1) in any of the anthropo

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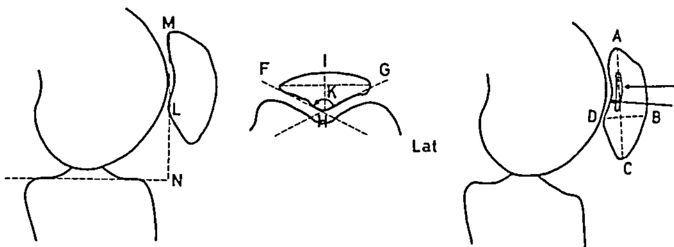


Fig 1 Morphometric variables Wiberg angle FHG Patellar depth index FG/HK Patellar shape index GH/FH Patellar relative thickness lateral BD/AC Patellar relative thickness axial view IH/FG Patella alta variable LN/ML E Excavation Sclerosis

Table 1

Distribution of roentgen morphometric variables between sexes and diagnostic groups (average ±SD)

Measurement	Women (n=33)	Men (n=33)	Normal (n=23)	Chondromalacia (n= 6)	Arthrosis (n=1?)
Sclerosis	0 05?±0 062	0 043±0 030	0 045±0 ?8	0 047±0 0 ?	0 051_0 085
Wiberg angle (degrees)	122±11	131±10	124±11	125±11	131±11
Patellar depth index	3 70±0 81	4 03±0 62	3 79±0 60	3 ?6±0 74	4 13±0 86
Patellar shape index	1 46±0 38	1 29±0 20	1 30±0 17	1 45±0 36	1 30+0 ?1
Patellar relative thickness lateral	0 43±0 04	0 43±0 05	0 44±0 05	0 43±0 04	0 4 _0 05
Patellar relative thickness axial view	0 47±0 04	0 43±0 05	0 46±0 05	0 44±0 05	0 46+0 05
Patella alta variable	0 84±0 13	0 80±0 15	0 84±0 16	0 84 0 1?	0 ?8+0 15

metric variables except for an increased frequency of a radiologically obvious excavation of the patella in the lateral view of patients with chondromalacia They differed significantly not only from controls (0 01>p>0 001) but also from cases with arthrosis (0 05>p>0 02 Table 2) Excavation was equally common in both sexes

Discussion

With improved radiographic technique and with a larger number of subjects it is possible that minor and significant differences may be demonstrated between anatomically normal patello-femoral joints and joints with chondromalacia However the data of the present series indicate that these differences could never be of such a magnitude that the measurement could be of diagnostic value for the individual patient with patello-femoral pain The finding of an excavation (Fig 2) seems to be more reliable In the present series this excavation occurred in all 26 patients with chondromalacia except two Excavation of the patellar subchondral

Table 2

Chi square representation of patellar excavation in relation to the diagnosis

Excavation	Normal	Chondromalacia	Arthrosis
None	11	-	7
Possible	6	5	1
Obvious	6	19	





Fig 2 Patellar excavation and the arthrotomy finding in the same patient 19 year old man with patello-femoral symptoms since one year Two months after radiography the knee was operated upon The lesion of the patellar cartilage was classified as chondromalacia grade III

bone was noted by HAGLUND (1926) who assumed that this abnormality was related to trauma FICAT (1970) referred to it as l encoche de Haglund ØWRE (1936) and others have stated that it is too common to be of clinical importance The abnormality is frequently observed in films of patients with chondromalacia illustrated in the literature and was commented upon by SMILLIE (1974) although it has not been systematically explored previously The excavation of the patellar subchondral bone in combination with a smooth or even bulging patellar cartilage at arthroscopy suggests that the patellar cartilage may be thicker than average Since it has been demonstrated by WIBERG and others that the patellar joint surface has the thickest hyalineous cartilage of all joints in the human body additional thickening may be an obstacle for the distribution and perfusion of fluid through the cartilage Therefore nutritional deficiencies which have been suggested as one cause of chondromalacia (HIRSCH 1944) may occur A causative relationship between the excavation of the subchondral bone and the chondromalacia or simply an interaction by some other unknown variable may exist Even if other diagnostic means today are available for the diagnosis of abnormalities in patello-femoral joint such as arthrography (HORNS 1977) and arthroscopy (LUND & NILSSON 1980) the radiologic abnormality described may be of interest for the evaluation of standard knee films

SUMMARY

In a series of patients in whom the patello-femoral joint had been examined by arthroscopy in conjunction with arthrotomy or both previously obtained films were reviewed A series of radiologic morphometric measurements with bearing on the shape of the patella and the patello-femoral joint was carried out and compared between patients who had normal patello-femoral joints patients with chondromalacia grade II or III and patients with chondromalacia grade IV or arthrosis No difference between the three groups in any of the variables was found However a shallow excavation in the subchondral bone was observed in the lateral view of the patella in most of those patients with proven chondromalacia patellae

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SACROILIAC JOINT INVOLVEMENT IN CLASSICAL OR DEFINITE RHEUMATOID ARTHRITIS

A DE CARVALHO and H GRAUDAL

Few reports have appeared concerning lesions of sacroiliac joint in connection with rheumatoid arthritis (SHARP 1957 DIXON & LIENCE 1961 SIEV & LAINE 1963 DIXON 1964 WILKINSON & KIKLE 1966) The present report is part of a radiologic survey of the progression of rheumatoid arthritis in all limb joints (DE CARVALHO et coll 1980) in the cervical spine (DE CARVALHO & GRAUDAL 1980) and in the sacroiliac joints The purpose is to describe this progression in relation to the duration of the disease and to investigate the association of certain clinical and laboratory manifestations with the more or less severe progression of the disease

Material and Methods

The material consisted of the same 188 patients with classical or definite rheumatoid arthritis described previously (DE CARVALHO et coll) A total of 564 radiographic examinations of the sacroiliac joints was performed The sacroiliac joints were exposed with the patient lying supine and the side concerned being raised by 15 to 25 In most cases postero anterior films were also exposed with the beam directed cranially 5 to 10° However in order to reduce the radiation dose these films were not taken if survey film of the pelvis was available All films were evaluated by the same observer (A C) without knowledge of the clinical findings

Arthritic lesions of the sacroiliac joints were classified according to 5 grades

Grade 0 normal findings
Grade 1 slight or doubtful changes (for example osteoporosis)
Grade 2 small but definite erosive lesions with blurring of the joint surfaces
Grade 3 more severe erosive lesions of the joint surfaces possibly with some degree of ankylosis caudally in the joint
Grade 4 definite ankylosis (Fig 1)

The frequency of the abnormalities was mapped in relation to the time of clinical onset of the disease As the degree of involvement of the right and the left sides was identical both sides are considered simultaneously in the following comments Together with the radiographic examinations a number of clinical and laboratory parameters were recorded For statistical purposes the mean degree of involvement of the sacroiliac joints which were examined in each period of duration of the disease was calculated For this purpose the weight 0 was attached to the grades 0 and 1 of the degree of involvement and the weights 1 to 3 were attached to the grades 2 to 4 This was done in order to avoid grade 1 which is an uncertain or non specific stage The mean degree of involvement as expressed in this manner was found to behave almost as a linear function of the square root of the duration of the disease and thus a linear regression analysis was justified The basic statistical method has been discussed previously (DE CARVALHO et coll)

After dividing the patients into two groups a group with positive findings (noduli high ESR etc) and a control group (without such findings but with rheumatoid arthritis) it was possible in each case to compare the regression lines by means of a scale 0 to 4 of the degree of divergence 0 means that no differ

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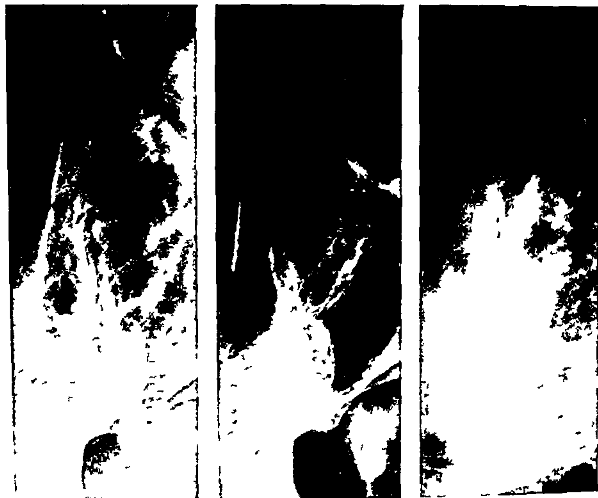


Fig 1 Grades 2 to 4 illustrated in the same joint with increasing duration of the disease

ence was found between the two groups 1 2 and 3 express increasing degrees of divergence between the distributions and degree 4 expresses two completely separated distributions Equivocal results were indicated by the letter E most frequently in cases of intersecting regression lines The figures of the 0 to 4 scale are accompanied by a sign + indicating a positive relation between the factor tested and more severe degrees of involvement of the joints Moreover the p-value was calculated in each case The parameters tested and the control groups appear in Table 2 Details concerning the laboratory parameters can be obtained from published reports (BICHEL et coll 1957 FABER & ELLING 1965 ELLING et coll 1967 DE CARVALHO & GRAUDAL 1980) For statistical purposes the duration of the disease was divided into periods of one year when the duration was 1 to 13 years With longer durations the periods were 14 to 15 16 to 17 18 to 20 and 21 to 25 years

Previously the average degree of involvement in 20 groups of limb joints and in each segment of the cervical spine was reported (DE CARVALHO et coll) For an analysis of the relation between the degree of involvement of these joint groups and the degree of sacroiliac lesion the series was divided into a group with positive finding and a control group using lesion of the sacroiliac joint as the distinguishing feature This was done as regards 27 joint groups (Table 3) The degree of divergence between the interest group and the control group was also classified according to the 0 to 4 scale

Results

The distribution of the radiologic abnormalities as related to the duration of the disease appears in Table 1 and Fig 2 The percentage of joints with grade 2 to 4 showed only a slight tendency to increase with the duration of the disease The percent

Table 1

Percentage of sacroiliac joints with rheumatoid arthritic lesions of grade 0 to 4 as related to the duration of the disease based on 564 radiographic examinations (1 128 joints)

Duration of the disease (years from onset)	No of classified joints	Severity of the affection				
		Grade 0	Grade 1	Grade 2	Grade 3	Grade 4
1–2	112	32 1	35 7	29 5	2 7	0
3–4	152	23	41 5	29 6	5 9	0
5–6	130	22 3	37 3	38 5	5 4	1 5
7–8	132	21 2	33 3	40 9	4 6	0
9–10	132	17 4	29 6	40 9	8 3	3 8
11–12	94	19 2	29 6	40 4	9 6	4 3
13–15	140	12 1	32 9	46 4	6 4	2 1
16–20	134	6	42 5	36 6	14 9	0
≥21	102	3	33 3	53 9	7 8	2

Table 2

Relationship between the course of rheumatoid arthritis in the sacroiliac joints and clinical and laboratory parameters

Group with positive findings	Controls	Degree of divergence (group with positive findings)	p <
Age at the onset ≥41 years	Remaining patients	+1	0 03
Women	Men	−1	0 1
Presence of subcutaneous nodules	No nodules	E	0 05
Elevated ESR (≥41 mm/h) at least at one time	Remaining patients	+1	0 005
Very elevated ESR (≥91 mm/h) at least at one time	Remaining patients	+1	0 005
Rheumatoid factor present Latex test or Rose Waaler test positive at least at one time	Rheumatoid factor absent in all investigations	0	0 5
Latex test and Rose Waaler test both positive at least at one time	Remaining patients	0	0 2
High titre of the Rose Waaler test (>160) at lest at one time	Remaining patient	−1	0 01
Very high titre of the Rose Waaler test (≥640) at least at one time	Remaining patients	0	0 25
Organ non specific antinuclear antibodies present (+ ++ or +++) at least at one time	Organ non specific anti nuclear antibodie absent in all investigation	0	0 06
Organ non specific antinuclear antibodies strongly positive (+++) at least at one time	Organ non specific ant nuclear antibodies absent + or ++ in all investigation	F	0 005
Granulocyte specific antinuclear antibodies present (+ ++ or +++) at least at one time	Granulocyte specific ant nuclear antibodies ab nt in all investigations	0	0 1
Granulocyte specific antinuclear antibodies strongly positive (+++) at least at one time	Granulocyte specific anti nuclear antibodies absent + or ++ in all investigation	(	0 3

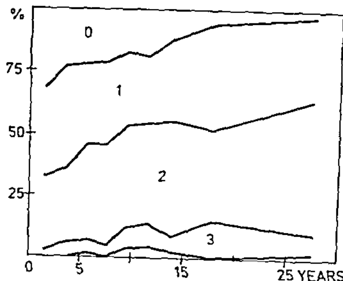


Fig 2 Distribution of grades 0 to 4 of joint involvement as related to the duration of the disease Areas between the curves express the relative frequency of each grade

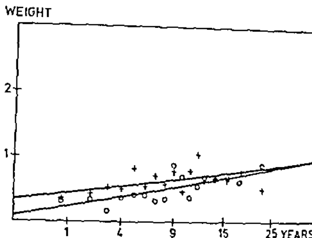


Fig 3 Relation between the average degree of sacroiliac joint involvement and an age >40 years at the onset of the disease (+) Controls (0) Degree of divergence +1 (p<0 03)

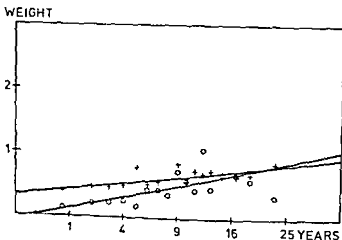


Fig 4 Relation between the average degree of sacroiliac joint involvement and an increased ESR (≥41 mm/h) at one time at least (+) Controls (0) Degree of divergence +1 (p<0 005)

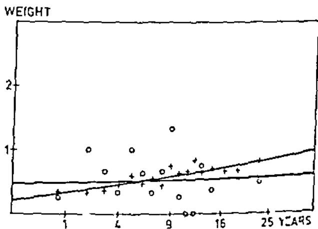


Fig 5 Relation between the average degree of sacroiliac joint involvement and presence of rheumatoid factor (+) Control (0) Degree of divergence 0 (p<0 5)

age with ankylosis (grade 4) was low and showed no tendency to increase with the duration of the disease Grade 3 was also relatively infrequent Most joints involved had slight erosive abnormalities (grade 2) while the remaining joints were normal or with unspecific abnormalities (grades 0 and 1)

The relationship between clinical and laboratory parameters and the severity of the involvement of the sacroiliac joints is given in Table 2 The apparent discrepancy between slight degrees of divergence ±1 and some significant or highly significant p-values is due to the fact that grade 3 and 4 lesions are rarely present This means that the average degree of involvement was low despite significant divergence between the groups tested The factors definitely related to more severe degrees of involvement were an age at onset ≥41 years (Fig 3) and an ESR ≥41 and ≥91 mm/h at least at one time (Fig 4) An inverse relation was found with Rose Waaler titre >160

No certain relationship was established between the degree of involvement and the following factors sex seropositivity for the rheumatoid factor positivity of both the Rose Waaler and the latex tests very high titres (≥640) of the Rose Waaler test and the presence or strong positivity of organ non specific and granulocyte specific antinuclear antibodies

The relationship between the degree of involvement of the sacroiliac joints and the remaining joint groups appears in Table 3

Psoriasis occurred only in two men and one

Table 3

Difference in the degree of affection of joint groups when the patients are selected according to the presence or degree of sacroiliac lesion and compared with controls. The degree of divergence between the regression lines for the average degree of affection expresses this difference

Joint group	SI joint affection of grade 3–4 at least once (as compared with the remaining patients)		SI joint affection of grade 2 at least once (as compared with the patient group where no certain lesion was detected)	
	Degree of divergence	p <	Degree of divergence	p <
C1–C2 segment	+2	0.001	0	0.8
C2–C3 segment	+2	0.0005	+1	0.03
C3–C4 segment	+1	0.001	+2	0.001
C4–C5 segment	+1	0.25	+2	0.0005
C5–C6 segment	+1	0.04	+2	0.0005
C6–C7 segment	0	0.6	+[illegible]	0.0005
C7–Th1 segment	+1	0.15	+2	0.0005
Shoulder	+3	0.0005	+2	0.0005
Elbow	+3	0.0005	0	0.6
Wrist	+3	0.0005	+1	0.01
CMC1 thumb	+4	0.0005	+2	0.005
CMC [illegible]–5	+4	0.0005	+2	0.0005
MCP 1 thumb	+3	0.0005	+1	0.1
MCP 2–5	+3	0.0005	+1	0.0005
PIP fingers	+3	0.0005	+1	0.01
IP 1 thumb	+1	0.[illegible]	0	0.3
DIP fingers	+2	0.04	0	0.[illegible]5
Hip	+4	0.0005	+3	0.0005
Knee	+4	0.0005	+1	0.02
Ankle	+3	0.0005	+3	0.0005
Tarsus	+3	0.0005	+3	0.0005
Midtarsal joint	+3	0.0005	+[illegible]	0.0005
MTP 2–5	+2	0.001	+2	0.001
MTP 1 hallux	+[illegible]	0.05	0	0.[illegible]
PIP toes	+2	0.0005	+1	0.04
IP 1 hallux	+2	0.0005	+[illegible]	0.0005
DIP toes	+1	0.1	0	0.4

C Cervical segment. CMC Carpometacarpal joints. MCP Metacarpophalangeal joints. PIP Proximal interphalangeal joints. DIP Distal interphalangeal joints. IP Interphalangeal joints. MTP Metatarsophalangeal joints.

…n who were seropositive, no seronegative pa… …had psoriasis.

Discussion

…general agreement concerning the value of the …nt projections for the sacroiliac joints exists.

The use of the oblique projection was based partly on tradition, partly on the desire not to change the technique in order to provide comparable results during a long period of observation. Others have preferred the postero-anterior projection (GRAINGER 1960), the antero-posterior projection (FORESTIER 1964) or tomography (WILKINSON &

MEIKLE) Although tomography was performed on several of the present patients the results have not been used for evaluation purposes in this report

The findings confirm that severe grades of sacroiliac lesions are rare in rheumatoid arthritis even after many years of the disease but small erosions occur rather frequently In other series of patients with rheumatoid arthritis abnormalities of the sacroiliac joints have been found in 47 per cent of 90 patients (SHARP et coll 1954) and in 36 per cent of 120 joints in advanced stages of the disease (DIXON) Unequivocal lesion was found in 22 per cent of 81 patients (MASON et coll 1959) Abnormalities that seem to correspond to grades 2 to 4 in the present classification have been found in 36 7 per cent of women with rheumatoid arthritis (SIEVERS & LAINE 1963) but also in 16 3 per cent of a control group The high percentage of grade 2 involvement after 1 to 2 years from the onset and the rather flat curves in Fig 2 suggest that at least part of the involvement may be caused by factors other than rheumatoid disease This is in accordance with the findings of DIXON & LIENCE and SIEVERS & LAINE On the other hand the positive relation of both grade 2 and 3 to 4 to severe involvement of practically all other joints and of grades 2 to 4 to a high ESR suggest a connection with the severity of rheumatoid arthritis However the positive relation of sacroiliac lesion to an age at onset ≥41 years distinguishes this involvement from that of all limb joints except the distal interphalangeal joints of the fingers and toes Moreover definite involvement of the sacroiliac joints was not associated with seropositivity for rheumatoid factor or with the presence of granulocyte specific antinuclear antibodies although these factors are associated with more severe degrees of involvement in most limb joints except the distal interphalangeal joints (DE CARVALHO & GRAUDAL) A positive relation to a higher age at onset and absence of relation to sex are features that differ from those of ankylosing spondylitis Furthermore the radiologic appearance differs from that of ankylosing spondylitis the tendency towards developing ankylosis was slight no tendency towards reactive sclerosis was found involvement more often occurred in the caudal ends of the joints erosions were often ill-defined pseudo-widening of the joint space was rarely found whereas narrowing was the rule

The findings in the sacroiliac joints give rise to the question what the abnormalities indicate Generally a relation to the severity of rheumatoid arthritis rather than the immunologic condition is suggested

SUMMARY

In 188 patients with rheumatoid arthritis 564 radiologic examinations of the sacroiliac joints were performed Severe blurring of the joint space or ankylosis were uncommon The involvement was related to an age >40 years at the onset high values of the ESR and involvement of most joint groups in the limbs and cervical spine Sex presence or high titres of the rheumatoid factor and antinuclear antibodies were unrelated to lesions of the sacroiliac joints A relation to the severity of rheumatoid arthritis rather than to the immunologic condition is suggested

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EXTERNAL BONY AUDITORY CANAL AND THE TYMPANIC BONE

Morphologic properties and influences on the tomographic reproduction

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The external auditory canal is developed postnatally At the time of birth the tympanic membrane attached to the border of the tympanic ring is situated in close relation to the surface of the skull At an early stage the brain capsule has a fairly even surface Several cranial superstructures as the supraorbital bone the otic and the mastoid bone develop postnatally and a gradual divergence between the internal and external skull surfaces occurs (WEINMANN & SICHER 1955) In the tympanic region the bone remodelling involves a development of the roof of the external auditory canal The tympanic bone develops directly from the C shaped ring at the middle ear This bone forms the floor and the anterior wall of the auditory canal which is normally closed in the third year of life (WEINMANN & SICHER)

The significance of morphologic variations and their influence on the reproduction in the tomographic images may be of clinical interest (VALVASSORI & PIERCE 1964 LAPAYOWKER & CLIFF 1969 ECKERDAL & AHLQVIST 1979) The morphology of the tympanic bone an integrated part of the temporomandibular joint and the external auditory canal varies (ECKERDAL et coll 1978) In the closed medial part of the skeletal auditory canal small defects can persist even in the adult stage WEINMANN & SICHER calculated the percentage to almost 20 while ECKERDAL et coll reported 5 2 per cent in an autopsy material

Factors influencing the tomographic reproduction may be defined in a generalized form Such analyses are most often made on different kinds of test objects of a well-defined nature (MATTSSON 1969 LITTLETON 1970) However in the diagnostic situation it is of interest to learn about the special image formation in the relevant morphologic area

In phantom experiments intended to decide the limits of reproduction of small skeletal defects in subtle bony walls of the head VON REISNER (1970) demonstrated the multi causal situation when reproducing true anatomic objects Not only the angulation of a bony wall but its thickness had a direct influence on the image formation Other factors were environmental such as adjacent high attenuating parts of the object relations to soft tissues or gasfilled cavities the tomographic movement and angulations ECKERDAL (1973) made an image formation analysis of generalized as well as specialized character in an investigation of the petrous bone and the proximal part of the mandible The conclusions as concerns image formation factors were in agreement with those of VON REISNER

The external auditory canal falls within the image field in several types of examinations The morphologic conditions including soft tissues and gasfilled cavities in the area of interest vary Consistently image phenomena may exist perhaps not even realized which in the individual diagnostic situation may be of interest

A morphologic radiographic investigation on an autopsy material was performed analysing the geometry and dimensions of different parts of the closed bony auditory canal the width of the tympanic bone separating the temporomandibular joint cavity and the auditory canal The osseous struc

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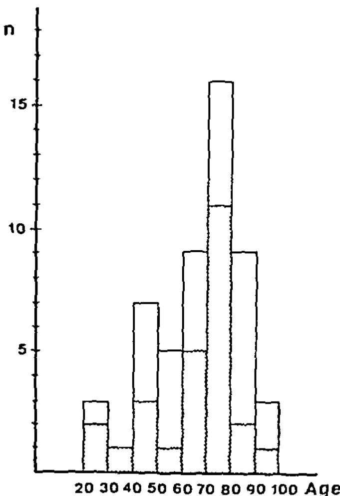


Fig 1 Age and sex distribution ◻ males ☐ females

tures of the tympanic bone were also analysed The morphologic base defined in this way created a basis for an analysis of the evaluation of clinical tomographic examinations and offered a possibility to analyse and describe some aspects of the nature of the tomographic hypocycloidal method per se

Material and Method

Fifty three autopsy specimens 26 males and 27 females consisting of the temporal bone and the proximal part of the mandible were used Age and sex distribution appear in Fig 1 The specimens were chosen at random during a 6-year period No known developmental disturbances were accepted The specimens were deep frozen embedded in carboxy methyl-cellulose and frozen in a mixture of dry ice and hexane (ULLBERG et coll 1971) Tomography of the specimen blocs was performed and sectioning in a microtome in corresponding sagittal layers (ECKERDAL 1973) The tomograph was Philips Massiot with hypocycloidal movement nominal focal size 0 6 mm the exposure time was 6

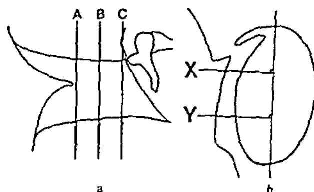


Fig 2 a) Diagrammatic representation of the external bony auditory canal in a p aspect Three sagittal morphologic layers A B C are indicated These layers were used in the morphometric calculation of the area of the auditory canal b) Diagrammatic representation of a sagittal morphologic layer The system used to calculate the thickness of the tympanic bone separating the auditory canal from the temporomandibular joint A line within the auditory canal approximately parallelized with a tangent to the posterior wall of the mandibular joint cavity was divided into three even parts The thinnest part of the tympanic bone inscribed between the perpendiculars X and Y was measured

seconds at 53 kV and 25 mA Siemens Saphir intensifying screens and Kodak RP film were used

Microradiography of the specimens was performed according to the technique previously described (ECKERDAL 1972) The microtome sections were adhered to a cellulose tape (3M 810) The information was gained from layers of different kinds which were related to each other with the aid of the three-dimensional orientation system visible in the tomograms as well as in photos of the specimen sections Thus the information was gained from tomograms microradiograms and histologic preparations of 20 mμ microtome sections (ECKERDAL 1973)

The microradiograms and sometimes as supplements the histologic sections adhered to the cellulose tape were projected and enlarged in a Werth Profile projector Record 72 as described by ECKERDAL & AHLQVIST The different measurements were taken on three sagittal sections integrated in a continuous series where the preserved individual layers were separated by 1 mm The selected sections were taken from the totally closed part of the bony auditory canal according to the system indicated in Fig 2 a In the schematic drawing of an auditory canal in a p aspect the chosen morphologic layers were A) the first lateral one where a total closure of the auditory canal is to be found B) a layer in the middle of the closed part of the canal with a length of 6 5 mm (mean value) and C) the last medial layer within the complete auditory canal When the individual closed auditory canal had an uneven millime

Table 1

Area (mm²) of the skeletal auditory canal in three different morphologic sections

Layer	Total group			Females			Males		
	x	S	Range	x	S	Range	x	S	Range
External	65 5	13 0	41 3–90 8	65 0	11 ?	48 0–87 3	66 1	14 8	41 3–90 8
Central	50 7	9 7	32 5–8? 8	51 6	10 6	36 0–8 8	50 0	8 8	3_ 5–69 8
Medial	47 5	9 8	33 8–78 8	47 9	10 4	36 3–78 8	47 1	9 3	33 8–73 3

ter length the central layer of calculation B was displaced one step medially in 45 cases and laterally in 8 cases The latter was due to inadequate quality in the preservation of these layers The level numbers could thus be 23 26 or 28 mm The thickness of the bony wall separating the auditory canal and the temporomandibular joint was recorded according to a system accounted for in Fig 2b A line within the auditory canal approximately parallelized with the tympanic wall was divided into three even parts The thinnest part of the tympanic bone inscribed between the perpendiculars X and Y was measured Taking the measurements on the enamel paper a sliding calliper was used The area of the closed part of the auditory canal was calculated on the tracings with an Aristo planimeter

Because the morphologic and positional factors were decided through the histologic and radiographic approach it proved to be possible to evaluate the tomographic images with close attention to the influence of morphologic variation in succeeding layers

Results

Morphologic considerations The external bony auditory canals proved to have continuous changes of calibre as well as of shape when analysed in succeeding sagittal layers tomographic or histologic The results of the calculations of the calibres of the sagittal projections of the canals are summarized in Table 1 The changes of the calibre are transformed and given in a two-dimensional and schematic drawing where the canal is given in a postero anterior view (Table 2) On the basis of these results the canals could be divided into 3 groups cone shaped hour glass shaped ovoid shaped The difference between the areas in layers A B C could be considerable despite the relatively short interindividual distances which depended on the total length of the canal These distances were maximally 5 mm but as a mean 3 mm In 4 cases the areas in the medial layers were 40 per cent of the lateral The corresponding value of the whole group was 75 per cent In one case only a remarkable widening was observed in the medial layer which was 68 per cent larger than the lateral Even the hour glass shaped canals proved to have lateral orifices larger than the medial (Table 1)

It was not only the calibre of the bony auditory canal which varied but also the shape as observed in lateral sections This was represented by a wide spectrum of for example strict circular oval heart shaped or triangular form (Fig 3) Different shapes could be present in the same specimen In some cases the main character could be oval but the angulation of its long diameter changed from layer to layer to describe a screw like canal (Figs 4 5)

The anterior bony wall of the auditory canal had rich morphologic variation The width of the wall is given in Table 3 The mean value of the width was similar in the lateral and central parts (A B) whereas the medial part (C) in the vicinity of the middle ear was considerably thinner The range of the wall dimensions was fairly wide 0 21 to 4 10 mm for the

Table 2

Relation between the areas in the three sagittal layers of the bony auditory canal transformed to a schematic drawing Three different types are recorded as regards calibre o shape me=middle ear

Shape	Number	Per cent
me	34	64 1
me	17	3 1
m	2	3 8

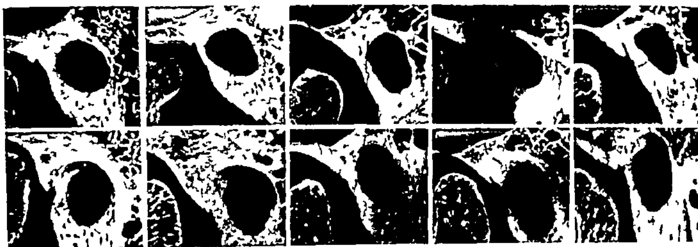


Fig. 3. The shape of the external bony auditory canal varies considerably, for example circular, oval, triangular, trapezoid and heart-shaped. Microradiography, 20 mμ sections from different specimens.

total group (Table 3). The values were greater regarding males but the differences between the sexes were not significant. The bony structure differed on comparing the very thin walls with the thick ones. The thin walls were composed of compact cortical bone. The thicker walls sometimes revealed a subtle structure composed of minute cavities. Some different types are illustrated in Fig. 6.

Radiographic considerations. Straight auditory canals with minor variation of the calibre were sharply delineated in the tomographic images, provided that the long axis of the canal was parallel or only deviated up to 15°. When the auditory canals had considerable calibre changes within short distances or too wide angulation, partly or totally, the tomographic images were characterized by marginal blurring. The character and degree of this blurring was related to the constellation of individual morphologic properties. When tomography of screwlike canals was performed it was possible in succeeding tomographic images to perceive a marginal tomographic blurring successively displaced around the periphery of the image of the canal (Figs 5, 6). Faint skeletal demarcations in the tomographic images of the tympanic bone found an explanation in the existence of ultimately thin bony walls. A true reproduction of the central and medial part of the canal in these cases demanded an optimum orientation of the tympanic bone. The tolerance of deviation from a parallel relation between the skeletal surface and a perpendicular was remarkably lower than the theoretic one for these thin bone walls.

Discussion

Comments on the methods. The areas inscribed within the contours of the canals (Table 1) cannot be simply transformed to length dimensions. The change of shape of the canals interferes with the dimensions of the auditory canal as they can be perceived in, for example, postero-anterior projections. Even if the measurements of the areas are

Table 3

Width of the tympanic bone in the anterior wall of the auditory canal

Layer	Width (mm)								
	Total group			Females			Males		
	$\bar{x}$	s	Range	$\bar{x}$	s	Range	$\bar{x}$	s	Range
Lateral	1.50	0.6[illegible]	0.34–3.65	1.4[illegible]	0.[illegible]4	0.34–[illegible].74	1.58	0.67	0.44–3.65
Central	1.50	0.7[illegible]	0.[illegible]6–4.10	1.4[illegible]	0.67	0.[illegible]6–[illegible].47	1.64	0.78	0.33–4.1
Medial	1.[illegible]1	0.5[illegible]	0.[illegible]1–[illegible].54	1.[illegible]	0.55	0.[illegible]1–[illegible].51	1.74	0.4[illegible]	0.55–[illegible].54

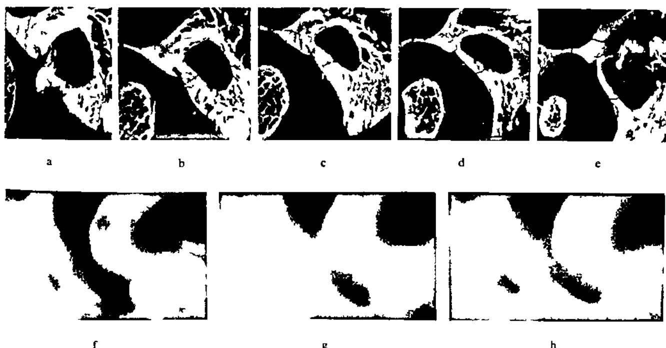


Fig 4 Different shapes of the bony auditory canal present in the same specimen The angulation of the long diameter of the bony auditory canal is gradually changing to describe a screw like canal The sections could be correlated according to the scheme

Sagittal levels of the images (mm)	Microradiography	22	5	27	29	31
	Tomography	25 3	27 3	29 3		

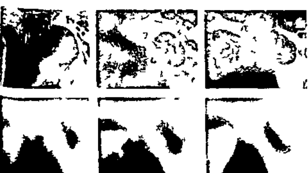


Fig 5

Fig 5 Change of the shape and angulation of the long diameter of the bony auditory canal Correlation scheme

Sagittal levels of the images (mm)	Microradiography	25	27	31
	Tomography	6	28	30

identical in the three observed layers the canal may seem to be cone shaped (Table 2)

The sagittal layers may randomly be at right angles to the long axis of the bony auditory canal but almost always a small deviation exists from this angle which is the optimum one as concerns reproduction in the tomographic image The ange relation can also vary within an individual canal depending on its curvature Should actual angle deviation be great this will affect the geometry of the projected bony auditory canal i e the round one is reproduced with oval form Angle deviations should be taken into account when evaluating the areal relations in Table 1

The bony wall separating the auditory canal and the joint was measured in the thinnest part of a central third according to the system demonstrated in Fig 2b It proved in some specimens to be difficult to decide a representative measurement distance The reason for this may be illustrated by Fig 5a where the bony wall has an extremely thin part in the superior fusion However this part cannot be representative for the thickness of the wall as a whole Therefore a fixed calculation system was preferred

Comments on the radiographic evaluation Despite a normal skeletal and soft tissue morphology the tomographic image may demonstrate blurred

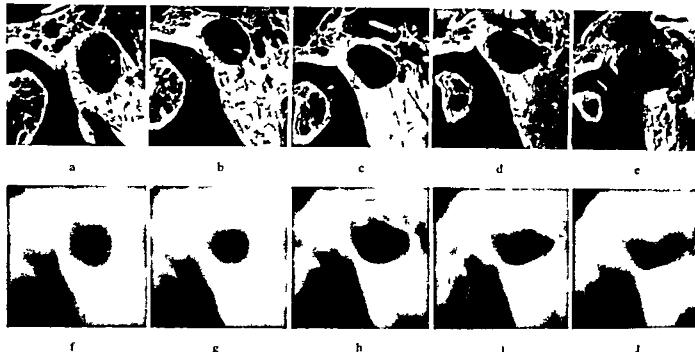


Fig 6 Marginal tomographic blur generated by the continuously changing shape diameter and angulation of the bony auditory canal Correlation scheme

Sagittal levels of the images (mm)						
	Microradiography	23	6	27	8	30
	Tomography	22	24	6	8	30



Fig 7

Fig 7 Clinical case with longstanding pain from the joint and ear a) Tomographic image from the initial examination revealed a possible osseous lesion b c) Repeat tomography Changed angle relation optimized as regards the tympanic bone This was intact the faint primary demarcation was due to a very thin bone wall and too wide angulation

contours generated by a too great angle between the surface of the skeletal part and a perpendicular to the tomographic table In the present series several morphologic explanations to a blurred depiction of skeletal contours of the auditory canal existed Certain auditory canals revealed considerable calibre changes within short layer distances sometimes supplemented by a slight bending of the osseous canal The demonstrated continuous change of the geometry of the canal in the lateral view was also an essential factor A special case was the screwlike canals where the blurred sector of the auditory canal described a gradual change of position which thus had a simple morphologic explanation A positional change at a new tomographic exposure will give a slight change in the appearances of blurred contours depending on the new tangential relations

The thickness of the tympanic bone differed considerably which was demonstrated by the range 0 21 to 4 10 (mm) The interplay between dimensional factors and angulations in contour creating in tomographic images systematically described by VON REISNER was observed also in this investigation An angle deviation of the thin walls was associated with strongly blurred contours or even a false image a discontinuity in the depiction of the skeletal demarcation of the auditory canal simulating a skeletal defect (ECKERDAL 1973 ECKERDAL & AHLQVIST) This is further illustrated in Fig 7 The patient was examined because of long term obscure pain from the ear and the temporomandibular joint The validity of the image of a skeletal defect in the primary image sequence was tested by an image in a changed angulation and by a comparison with the contralateral auditory canal The contour of the tympanic bone was reproduced in the second sequence The tympanic bone on the control side proved to be thicker which also was a diagnosti

problem. It is not known from the literature to what extent a skeletal asymmetry in this region must be expected. The explanations mentioned of total or partial blurring of skeletal contours have had skeletal morphologic explanations as well as positional.

An essential question is how to differentiate an image with incomplete skeletal demarcations depending on a pathologic process of the bone from those where the explanation will be morphologic or positional. In an early phase of a pathologic process perhaps only characterized by a broken cortical surface it is not always possible to make a simple and valid differential diagnosis based on tomography. This may seem to be confusing. The ordinary opinion about the high tomographic efficiency is based on results from investigations which are concerned with the tomographic reproduction of details (VON REISNER, ECKERDAL 1973). However, the objects of these investigations are often well circumscribed and defined defects even located on other morphologic entities. The character of these defects often differs from that of primary cortical osseous defects of inflammatory or tumorous origin. This fact explains why the capacity of detail reproduction is not an indisputable parameter in estimating the efficiency of tomography in reproducing early pathologic non penetrating processes in the tympanic bone. Differential diagnostic problems may be caused by anatomic defects (ECKERDAL et coll.) and in particular possible asymmetry between the two sides. It is of clinical interest to achieve a comparable positioning of the patient on the tomographic table in order to avoid false evaluation.

The perception of the contours of thin skeletal parts may be influenced by attenuation generated by additional soft tissues of inflammatory or tumorous origin. Already blurred contours are naturally most apt to be further extinguished. The limit of reproduction may even be exceeded. This could seem to be opposed to the findings of VON REISNER. He concluded that the reproduction in tomographic images of small skeletal defects in bony partitions was not affected by the presence or absence of soft tissue in or immediately around the actual defect. But he made some essential additional assumptions that the bony partitions were not too thin, the defects larger than 4 mm and the reproducible conditions in other respects favourable.

SUMMARY

The external bony auditory canal is morphologically defined as concerns the shape and calibre in successive plane parallel histologic sections of the petrous bone. The sagittal dimensions and structural appearances of the tympanic bone are demonstrated. The morphologic properties defined constitute a basis for the evaluation of the tomographic image formation in this region.

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